U.S. DEPARTMENT OF COMMERCE
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PB-264 349

Assessment of Industrial Hazardous Waste Practices. Electroplating and Metal Finishing Industries - Job Shops

Battelle Columbus Labs, Ohio

Prepared for

Environmental Protection Agency, Washington, D C Hazardous Waste Management Div

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BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No. PB-264 349

4. Title and Subtitle
Assessment of Industrial Hazardous Waste Practices - Electroplating and Metal Finishing Industries - Job Shops

5. Report Date September 1976

6.

7. Author(s)
Hallowell, J.B., Vaaler, L.E., Gurklis, J.A., Layer, C.H.

8. Performing Organization Rept. No. G-2959

9. Performing Organization Name and Address
Battelle's Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

10. Project/Task/Work Unit No.

11. Contract/Grant No.
EPA No. 68-01-2664

12. Sponsoring Organization Name and Address
EPA, Hazardous Waste Management Division
Office of Solid Waste
Waterside Mall
Washington, D.C. 20460

13. Type of Report & Period Covered Final,
June, 1974 - Sept., 1976

14.

15. Supplementary Notes
EPA Project Officer - Timothy Fields, Jr.

16. Abstracts The organization of this report follows four phases: Industry Characterization, Waste Characterization, Treatment & Disposal Technology, and Cost Analysis. The heaviest concentration of electroplating and metal finishing facilities is in the North Central Region of the U.S., followed by the Atlantic Coast states and the State of California. Four types of wastes were identified as being destined for land disposal: water pollution control sludges, process wastes, degreaser sludges, and salt precipitates from electroless nickel bath regeneration. Estimated quantities of waste destined for land disposal by industry (job shops) during 1975, 1977, and 1983 are shown. The three levels of treatment and disposal technology defined for the disposal of wastes from job shops are Level I - prevalent practice; Level II - best technology currently used: and Level III - practice considered environmentally adequate. The costs for treatment and disposal of wastes at Level I are significantly higher than those for Levels II and III because Level I technology involves treatment and disposal of sludge containing 5% solids as opposed to sludge containing 20% solids for Levels II and III. Dewatering the sludge results in a 4.4-fold reduction in the volume of sludge.

17. Key Words and Document Analysis. **17a.** Descriptors

Solid Wastes
Potentially Hazardous Wastes
Electroplating Wastes
Waste Disposal Technology
Waste Disposal Costs
Solid Waste Projections

17b. Identifiers/Open-Ended Terms

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

17c. COSATI Field/Group

18. Availability Statement
Available from National Technical Information Service, Springfield, VA 22161

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 516

22. Price

ASSESSMENT OF INDUSTRIAL HAZARDOUS WASTE PRACTICES - ELECTROPLATING AND METAL FINISHING INDUSTRIES - JOB SHOPS

This final report (SW-136C) describes work performed for the Federal solid waste management programs under contract no. 68-01-2664 and is reproduced as received from the contractor.

U.S. ENVIRONMENTAL PROTECTION AGENCY

1977

This report has been reviewed by the U.S. Environmental Protection Agency and approved for publication. Its publication does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement or recommendation for use by the U.S. Government.

An environmental protection publication (SW-136c) in the solid waste management series.

EXECUTIVE SUMMARY

Introduction

This report is the result of a study commissioned by the U.S. Environmental Protection Agency to assess the "Industrial Hazardous Waste Practices -- Electroplating and Metal Finishing Industries" (SIC 3471). This is one of a series of industry studies by the Office of Solid Waste, Hazardous Waste Management Division. The studies were conducted for information purposes only and not in response toa Congressional regulatory mandate. As such, the studies serve to provide EPA with: (1) an initial data base concerning current and projected types and quantities of total industry and potentially hazardous wastes and applicable disposal methods and costs; (2) a data base for technical assistance activities; and (3) a background for guidelines development work.

Although metal finishing embraces many industrial operations, this study was limited to:

(1) Electroplating
(2) Anodizing and dyeing
(3) Electroless and immersion plating
(4) Chemical conversion coating (phosphate, chromate, etc.)
(5) Chemical polishing and electropolishing.

Specifically excluded from the study were:

(1) Coloring
(2) Chemical milling and etching
(3) Electrochemical machining
(4) Pickling, descaling, bright dipping, stripping
(5) Electropainting.

There is no accurate information on the number and location of all of the electroplating and metal finishing operations in the U.S. (recent estimates of the number of installations range from 3,000 to 22,000)*. Included in this segment of industry are small, independent companies which employ only a few persons and do specialty plating and large, complex installations owned and operated by major manufacturers as a service facility.

The definition of "potentially hazardous waste" in this study was developed on the basis of contractor investigations and professional judgment. This definition does not necessarily reflect EPA thinking since such a definition, especially in a regulatory context, must be broadly applicable to widely differing types of waste streams. Obviously, the presence of a toxic substance should not be the major determinant of hazardousness if there were mechanisms to represent or illustrate actual effects of wastes in specified environments. Thus, the reader is cautioned that the data presented in this report constitute only the contractor's assessment of the hazardous waste management problem in this industry.

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* Federal Register, Vol. 40, No. 80, Thursday, April 24, 1975, p. 18133.

The basic objectives of this study are discussed in the report in four major sections:

(1) Industry Characterization. To develop an industry profile in terms of number of plants, geographical distribution, plant size, age of plants, products produced, and production distribution.

(2) Waste Characterization. To identify the types of wastes, their source, their chemical form, and the quantity of total industry and potentially hazardous wastes generated during 1975, with projections for 1977, and 1983.

(3) Treatment and Disposal Technology. To identify treatment/disposal technologies now and to be explored in the future by the industry for those potentially hazardous wastes.

(4) Cost Analysis. To determine and analyze the costs associated with the above treatment and disposal practices.

The results of this study are presented in the sections of this report which follow. The organization of the report generally follows the four phases described above, i.e., Industry Characterization, Waste Characterization, Treatment and Disposal Technology, and Cost Analysis.

Program Methodology

The data collected for this study were obtained from four different sources. The first source was the published and unpublished literature, such as trade journals, technical literature, and government reports.

The second source of data was the various industry trade associations. The National Association of Metal Finishers, the American Electroplaters Society, Inc., the Metal Finishing Suppliers Association, and the Institute of Printed Circuits participated in the study.

The third method of data acquisition was the distribution by mail of a questionnaire to more than 7,000 electroplating and metal finishing facilities through the National Association of Metal Finishers. The response to the questionnaire was very poor. Only 130 facilities returned the questionnaire.

The fourth method of data acquisition was through personal contacts and telephone conversations with personnel associated with the electroplating and metal finishing facilities, and with waste treatment and disposal contractors. The number of visits made to and telephone conversations with each of these two groups was as follows:

	Electroplating and Metal Finishing Facilities	Treatment/Disposal Contractors
Plant Visits	29	17
Telephone Conversations	90	37

A waste sampling and analysis program was not a part of this study since it was felt initially that enough data were available regarding the constituents which might appear in electroplating and metal finishing industry wastes.

Industry Characterization

Geographic Distribution and Size

The geographic distribution and size of the electroplating and metal finishing industry (job shops) were determined using the state directories of manufacturers. A total of 2,254 job shops were identified. Additionally, use of the data from other state directories enabled the contractor to develop a breakdown as to the size of the towns in which electroplating and metal finishing establishments are located (Table 1).

As shown in Table 1, the heaviest concentrations of electroplating and metal finishing facilities are in the North Central Region of the U.S. EPA Region V has nearly 40 percent of the total number of industry job shops, with Michigan accounting for 12 percent, followed by Ohio and Illinois, with 11 percent and 8 percent, respectively, of the job shops. The Atlantic Coast states, EPA Regions I, II, and III, are second with nearly 35 percent of the electroplating and metal finishing plants. The third heaviest concentration is in EPA Region IX, particularly in the State of California, with 6 percent of the job shops. The remaining sectors of the country share 20 percent of the electroplating and metal finishing plants.

Evaluation of the data presented in Table 1 also shows that more than 52 percent of all electroplating and metal finishing establishments are located in cities having a population greater than 100,000, and more than three-quarters of the plants are located in cities with a population greater than 20,000. It is reasoned that the urban location of the job shop portion of the industry would result in limits (either physical or economic) of plant space available for the treatment and disposal of wastes and also would be associated with wastewater disposal to sewers according to applicable local regulations. Thus, the distribution cited above would favor such waste disposal practices as sewering of liquid wastes (with or without treatment or solids separation) and off-site disposal of nonsewerable wastes, and therefore the use of contractor services.

TABLE 1. DISTRIBUTION OF PLANTS GEOGRAPHICALLY AND BY CITY POPULATION(1-51)

EPA Region and State	Number of Plants[a]					Percent Distribution of Plants[a]				
	A	B	C	D	Total	A	B	C	D	Total
Region I	16	55	135	120	326	0.71	2.44	6.00	5.33	14.48
Massachusetts	7	16	59	34	116	0.31	0.71	2.62	1.51	5.15
Connecticut	7	29	51	37	124	0.31	1.29	2.27	1.64	5.51
Rhode Island	0	5	23	49	77	----	0.22	1.02	2.18	3.42
New Hampshire	1	2	0	0	3	0.04	0.09	----	----	0.13
Maine	1	0	2	0	3	0.04	----	0.09	----	0.13
Vermont	0	3	0	0	3	----	0.13	----	----	0.13
Region II	44	37	64	132	277	1.95	1.64	2.84	5.91	12.34
New Jersey	16	22	36	39	113	0.71	0.98	1.60	1.73	5.02
New York	28	15	28	93	164	1.24	0.67	1.24	4.13	7.28
Region III	33	34	37	72	176	1.47	1.51	1.64	3.15	7.77
Delaware	0	0	0	1	1	----	----	----	0.04	0.04
Maryland	1	2	3	14	20	0.04	0.09	0.13	0.62	0.88
Pennsylvania	28	30	25	55	138	1.24	1.33	1.11	2.44	6.12
Virginia	1	0	0	2	3	0.04	----	----	0.09	0.13
West Virginia	3	2	9	0	14	0.13	0.09	0.40	----	0.62
Region IV	29	20	41	67	157	1.29	0.89	1.82	2.98	6.98
Alabama	5	2	8	6	21	0.22	0.09	0.36	0.27	0.94
Florida	7	4	13	17	41	0.31	0.18	0.53	0.76	1.83
Georgia	3	1	3	9	16	0.13	0.04	0.13	0.40	0.70
Kentucky	2	3	1	6	12	0.09	0.13	0.04	0.27	0.53
Mississippi	2	2	2	2	8	0.09	0.09	0.09	0.09	0.36
North Carolina	5	3	5	10	23	0.22	0.13	0.22	0.44	1.01
South Carolina	4	2	4	2	12	0.18	0.09	0.18	0.09	0.54
Tennessee	1	3	5	15	24	0.04	0.13	0.22	0.67	1.06
Region V	89	104	174	494	861	3.95	4.62	7.73	21.95	38.25
Illinois	8	14	44	123	189	0.36	0.62	1.95	5.46	8.39
Indiana	8	13	22	26	69	0.36	0.58	0.98	1.16	3.08
Michigan	49	35	55	137	276	2.18	1.55	2.44	6.09	12.26
Minnesota	3	4	6	18	31	0.13	0.18	0.27	0.80	1.38
Ohio	16	34	33	179	262	0.71	1.51	1.47	7.95	11.64
Wisconsin	5	4	14	11	34	0.22	0.18	0.62	0.49	1.51
Region VI	2	7	13	77	99	0.09	0.31	0.58	3.42	4.40
Arkansas	0	1	2	2	5	----	0.04	0.09	0.09	0.22
Louisiana	0	0	1	1	2	----	----	0.04	0.04	0.09
New Mexico	0	0	0	6	6	----	----	----	0.27	0.27
Oklahoma	0	1	0	17	18	----	0.04	----	0.76	0.80
Texas	2	5	10	51	68	0.29	0.22	0.44	2.27	3.02
Region VII	14	15	15	71	115	0.62	0.67	0.67	3.15	5.11
Iowa	7	2	9	4	22	0.31	0.09	0.40	0.18	0.98
Kansas	1	7	0	13	21	0.04	0.31	----	0.58	0.93
Missouri	6	5	6	50	67	0.27	0.22	0.27	2.22	2.98
Nebraska	0	1	0	4	5	----	0.04	----	0.18	0.22
Region VIII	2	2	4	23	31	0.09	0.09	0.18	1.02	1.38
Colorado	1	1	2	18	22	0.04	0.04	0.09	0.80	0.98
Montana	1	0	0	0	1	0.04	----	----	----	0.04
North Dakota	0	0	0	0	0	----	----	----	----	----
South Dakota	0	0	1	0	1	----	----	0.04	----	0.04
Utah	0	1	1	5	7	----	0.04	0.04	0.22	0.31
Wyoming	0	0	0	0	0	----	----	----	----	----
Region IX	3	14	52	94	163	0.13	0.62	2.31	4.04	7.11
Arizona	1	1	1	15	18	0.04	0.04	0.04	0.67	0.80
California	1	13	48	74	136	0.04	0.58	2.13	3.29	6.04
Hawaii	0	0	0	3	3	----	----	----	0.13	0.13
Nevada	1	0	3	2	6	0.04	----	0.13	0.09	0.27
Region X	0	1	13	35	49	----	0.04	0.58	1.55	2.18
Alaska	0	0	0	0	0	----	----	----	----	----
Idaho	0	0	3	0	3	----	----	0.13	----	0.13
Oregon	0	0	4	18	22	----	----	0.18	0.80	0.98
Washington	0	1	6	17	24	----	0.04	0.27	0.76	1.07
Total United States	232	289	548	1,185	2,254	10.29	12.82	24.3	52.57	100.00

(a) Classified by City Population: A = <5000; B = 5000 to 20,000; C = 20,000 to 100,000; D = >100,000.

Distribution by Number of Employees

The distribution of job shops by number of employees is given in Table 2. Examination of this table reveals that the greatest percentage (30 percent) of the total number of shops have 11-25 employees; 27 percent have 5-10 employees; 20 percent, 26-50 employees; and 12 percent, 1-4 employees. Thus, 89 percent of the total number of job shops have between 1 and 50 employees.

Distribution by Age of Facilities

A sampling of the industry established no definite pattern regarding the age range among facilities. Companies report having equipment as new as 2 years or as old as 30 years. Waste treatment equipment for chemical in-line or end-of-line wastewater control is generally less than 5 years old, although some equipment in a few cases has been used for about 25 years.

Distribution by Types of Operations

Most electroplating or metal finishing operations involve a sequence of unit operations which may be classified as prefinishing, finishing, and postfinishing operations. Prefinishing operations are those which clean and otherwise prepare a surface for finishing, such as deburring, degreasing, acid pickling, and alkaline cleaning. Finishing operations include the application of one or more electroplates, such as copper, nickel, chromium, zinc, or anodizing, and electroless plating. Postfinishing operations include bright-dipping, passivating, chromating, phosphating, buffing, and polishing.

Information supplied by the industry job shops during this study indicates that there are a total of 12 electroplating and metal finishing processes, with most of the operations being electroplating. Of the 130 plants providing information, 65 have electroplating lines depositing 14 different metals or alloys in 265 rack- or barrel-type operations. It is concluded that four different metals or alloys are deposited on the average per job shop.

Value Added and Cost Information

Job shops are included in Standard Industrial Classification (SIC) 3471 as part of the metal services industries doing work on materials owned by others. For 1972, the value added by manufacture was $749,100,000. The

TABLE 2. DISTRIBUTION OF ELECTROPLATING AND METAL FINISHING JOB SHOPS BY NUMBER OF EMPLOYEES

EPA Region and State	Number of Employees										
	1-4	5-10	11-25	26-50	51-75	76-100	101-150	151-250	251-500	Not Given	Total
Region I	53	66	55	116	7	10	1	6	—	12	326
Massachusetts	23	25	31	29	—	6	—	—	—	2	16
Connecticut	30	36	22	15	6	3	1	1	—	10	124
Rhode Island	—	—	—	71	—	1	—	5	—	—	77
New Hampshire	—	1	2	—	—	—	—	—	—	—	3
Maine	—	2	—	—	1	—	—	—	—	—	3
Vermont	—	2	—	1	—	—	—	—	—	—	3
Region II	1	73	110	53	13	8	5	1	—	13	277
New Jersey	1	41	44	18	3	1	2	—	—	3	113
New York	—	32	66	35	10	7	3	1	—	10	164
Region III	42	38	51	25	5	7	2	—	—	6	176
Delaware	—	—	1	—	—	—	—	—	—	—	1
Maryland	7	4	7	2	—	—	—	—	—	—	20
Pennsylvania	35	30	39	17	4	5	2	—	—	6	138
Virginia	—	—	—	2	1	—	—	—	—	—	3
West Virginia	—	4	4	4	—	2	—	—	—	—	14
Region IV	22	42	42	34	6	5	1	1	1	3	157
Alabama	—	9	5	5	—	1	—	—	—	1	21
Florida	9	13	13	3	1	—	—	—	—	2	41
Georgia	5	3	3	2	2	—	1	—	—	—	16
Kentucky	1	3	1	5	1	1	—	—	—	—	12
Mississippi	—	1	6	—	—	1	—	—	—	—	8
North Carolina	2	4	7	8	—	1	—	1	—	—	23
South Carolina	1	4	4	1	2	—	—	—	—	—	12
Tennessee	4	5	3	10	—	1	—	—	1	—	24
Region V	88	215	247	120	42	24	16	12	4	93	861
Illinois	19	53	57	32	10	5	6	2	1	4	189
Indiana	—	21	26	10	—	6	—	3	—	3	69
Michigan	19	54	69	32	16	8	4	3	2	69	276
Minnesota	—	6	12	4	3	—	—	1	—	5	31
Ohio	50	73	71	38	11	3	5	3	—	8	262
Wisconsin	—	8	12	4	2	2	1	—	1	4	34
Region VI	8	30	31	18	2	9	—	—	—	1	99
Arkansas	—	2	—	2	—	1	—	—	—	—	5
Louisiana	—	1	—	1	—	—	—	—	—	—	2
New Mexico	—	5	—	1	—	—	—	—	—	—	6
Oklahoma	8	4	3	1	2	—	—	—	—	—	18
Texas	—	18	28	13	—	8	—	—	—	1	68
Region VII	22	28	34	11	3	10	6	—	1	—	115
Iowa	—	15	—	3	—	2	2	—	—	—	22
Kansas	—	—	14	—	—	4	3	—	—	—	21
Missouri	22	13	17	6	3	4	1	—	1	—	67
Nebraska	—	—	3	2	—	—	—	—	—	—	5
Region VIII	—	16	6	4	3	2	—	—	—	—	31
Colorado	—	12	2	3	3	2	—	—	—	—	22
Montana	—	1	—	—	—	—	—	—	—	—	1
North Dakota	—	—	—	—	—	—	—	—	—	—	—
South Dakota	—	1	—	—	—	—	—	—	—	—	1
Utah	—	2	4	1	—	—	—	—	—	—	7
Wyoming	—	—	—	—	—	—	—	—	—	—	—
Region IX	13	41	55	33	6	4	2	3	1	5	163
Arizona	2	5	6	4	—	1	—	—	—	—	18
California	7	31	49	29	6	3	2	3	1	5	136
Hawaii	2	1	—	—	—	—	—	—	—	—	3
Nevada	2	4	—	—	—	—	—	—	—	—	6
Region X	8	18	15	4	2	1	—	—	—	1	49
Alaska	—	—	—	—	—	—	—	—	—	—	—
Idaho	—	1	2	—	—	—	—	—	—	—	3
Oregon	8	5	5	—	2	1	—	—	—	1	22
Washington	—	12	8	4	—	—	—	—	—	—	24
Total Regions I-X	257	567	646	418	89	80	33	23	7	134	2254

cost of materials and fuels was $297,400,000, or about 40 percent of the value added. The capital expenditures in 1972 were $41,000,000, up 32 percent from 1971. Wages in 1972 were $393,300,000, an increase of 8 percent over the previous year, and represented 52 percent of the value added. During the period 1971 to 1972, industry employment rose 0.75 percent.

Waste Characterization

Types and Sources of Wastes

The job shop segment of the electroplating and metal finishing industry is characterized by many individual variations in both practice and facilities. The service offered by this industry may vary from a single operation to multiple-step processing. Although these operations may be classified in many ways, for the purpose of characterizing the wastes, they have been classified into three different categories: mechanical, chemical, and electrochemical.

Mechanical operations include: grinding, grit blasting, shot blasting, buffing, deburring, and polishing.

Chemical processes include: degreasing, acid pickling, alkaline cleaning, acid cleaning, surface neutralizing, chromating, phosphating, bright dipping, chemical polishing, passivating, and stripping. A special case in this category is electroless nickel and electroless copper plating, in which the surface of the workpiece acts as a catalyst for the decomposition of the solution, with the deposition of a metal on the workpiece.

Electrochemical processes in the industry include: anodic cleaning, cathodic cleaning, anodizing, and electroplating. Special cases under this category would include those processes which use no external electrical connections but depend on the electrochemical reactions between the basis material and the solution to produce a metallic coating, such as stannating and zincating. These latter processes are referred to as immersion plating.

The operations summarized above may be performed singly or in combination to produce the surface properties desired by a customer. They are the sources of the various potentially hazardous waste streams which are generated by this industry. The relationship of these sources to the potentially hazardous wastes which may be generated is shown in Figure 1.

In performing the study of the electroplating and metal finishing industry, four types of wastes were identified as being destined for land disposal. These are:

Water pollution control sludges
Process wastes
Degreaser sludges
Salt precipitates from electroless nickel bath regeneration.

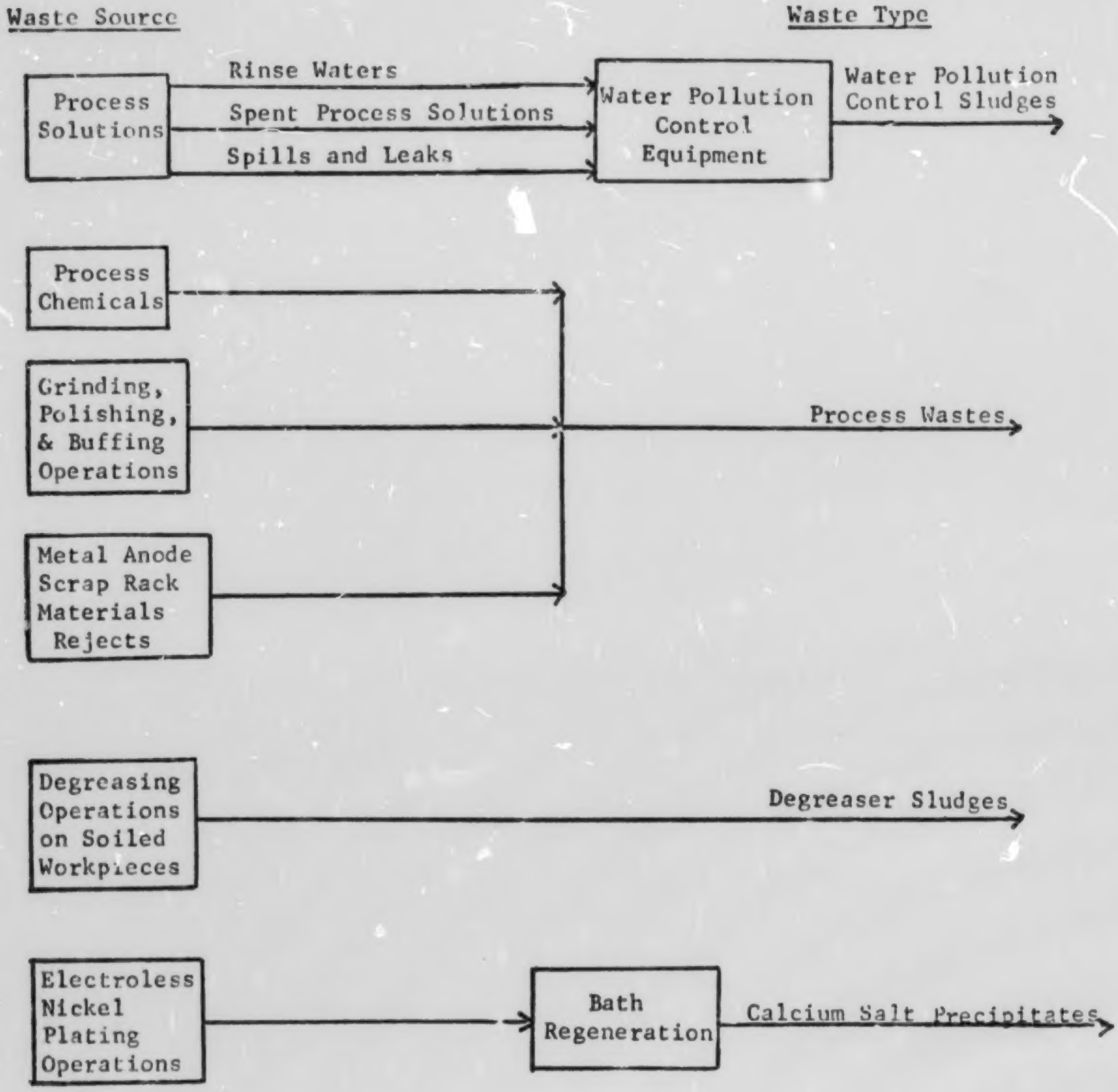
Waste Source
Waste Type
Process Solutions
Rinse Waters
Spent Process Solutions
Spills and Leaks
Water Pollution Control Equipment
Water Pollution Control Sludges
Process Chemicals
Grinding, Polishing, & Buffing Operations
Metal Anode Scrap Rack Materials Rejects
Process Wastes
Degreasing Operations on Soiled Workpieces
Degreaser Sludges
Electroless Nickel Plating Operations
Bath Regeneration
Calcium Salt Precipitates

FIGURE 1. GENERALIZED DIAGRAM OF TYPES AND SOURCES OF WASTES --- ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS)

Water pollution control sludges have been identified as a class because they constitute the largest single waste category destined for land disposal. (Although the majority of facilities do not treat their wastewater and thus do not generate sludge at present, pending regulations will require such treatment with the concommitant generation of these sludges.) Water pollution control, when practiced at an electroplating and metal finishing plant, will precipitate the dissolved, potentially hazardous materials, thus generating a waste for land disposal.

Process waste materials include grinding, polishing, and buffing wastes; filter aids; anode sludges and anode bags; and plating racks and rack materials. Most of these materials bear occluded or absorbed process chemicals and generally are disposed in landfills.

Degreaser sludges arise from chlorinated hydrocarbons, which are used to remove grease and oil from mechanically finished parts by polishing and buffing. These sludges then contain dissolved greases and oils, buffing compounds, abrasives, cloths, and metals. They may be discarded through the routes of direct disposal to the land or may be routed to a reclamation operation (e.g., distillation).

Salt precipitates from electroless nickel plating operations are produced during the regeneration of the bath composed of calcium orthophosphite and calcium sulfate. This particular type of waste may not always be present because electroless nickel plating operations are not as common as electroplating or because small volume solutions are not regenerated.

Criteria for Establishing Hazardous Wastes

In this study, the first criterion for designating a waste as potentially hazardous has been the destiny of the waste material--to be included the waste must be destined for land disposal. The four classes of wastes described above meet this criterion. Materials which normally are reclaimed, e.g., used degreasing solvents, have not been included because the reclaimed solvents are recycled or sold. Other materials which have not been included as a separate class are spent pickling and plating baths. In some instances these materials may be sent to a reclaimer and thus do -ot meet the land disposal criterion; in other instances, they are metered into the water pollution control system and become a part of the waste category termed "water pollution control sludges".

The second--and more important--criterion for inclusion of a material as a potentially hazardous waste is its possible detrimental effects upon human health and ecology and the possible degradation of ground and surface waters. The specific data on the toxic effects of the wastes from this industry which are destined for land disposal are very sparse. In addition, little is known about possible synergistic effects. The most widely accepted basis for defining many of these materials as potentially hazardous are the relatively low acceptable levels of the various metals in drinking water. Values derived from water quality criteria for the State of California are shown in Table 3.* In most cases, the acceptable levels of the metals commonly found in electroplating and metal finishing wastes are less than 0.1 ppm. Wastes containing any of these metals in a concentration equal to or more than that listed are considered potentially hazardous. On this basis, all known wastes from electroplating and metal finishing operations are defined as potentially hazardous. Proper treatment or disposal can eliminate the potential hazard.

The organic solvents used for degreasing operations usually are polychlorinated hydrocarbons--a class of organic chemicals which has received wide publicity for its carcinogenicity. Since these solvents are present in the degreaser sludges, another class of components is added to the list of potentially hazardous constituents generated by the electroplating and metal finishing industry which are destined for land disposal.

Because all of the four classes of wastes previously listed either contain heavy metals and/or polychlorinated hydrocarbons, all of these wastes are considered potentially hazardous.

Determination of Quantity of Wastes Generated

Estimates of the quantity of wastes currently generated and expected in the future from the electroplating and metal finishing industry were developed based on the data obtained for three model plants, statistical data, and responses from industry. The use of models and statistical data was necessitated by the poor response to several requests for actual plant data.

The following items were evaluated in the development of the three model plants:

- Plant size
  - number of employees
  - industry production rates
- Product mix
  - plating process, consisting of a major portion of copper, nickel, chromium, and zinc plating; with anodizing, electroless nickel, cadmium, and other finishes represented in a minor portion of the product mix.
  - a mix of automated and manual operations compatible with the number of employees
  - base metal to be finished
- Plant operating criteria based on electroplating engineering technology, including
  - preplating, plating, and postplating steps
  - solution compositions
  - bath dump rates, spills, and leaks
  - area plated

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* McKee, J. E., and H. W. Wolfe. Water Quality Criteria. 2nd Ed., Publication No. 3-A, Resources Agency of California, State Water Quality Control Board, 1963.

TABLE 3. WASTE CONSTITUENTS AND POTENTIALLY HAZARDOUS CONCENTRATION LEVELS

Waste Constituents	Potentially Hazardous Concentration, ppm[(a)]
Arsenic	0.05
Beryllium	0.2
Cadmium	0.05
Chromium	0.05
Copper	0.02
Cyanide	0.01
Gold	0.4
Iron	0.1
Lead	0.1
Manganese	300
Mercury	0.004
Nickel	0.8
Oil and Grease	7
Palladium	7
Phosphates	545
Selenium	0.05
Silver	0.003
Sulfates	200
Tin	1.2
Zinc	0.01

(a) Concentration which produces damage to human health, livestock, and/or aquatic organisms.

    - tank sizes or solution volumes
    - solution drag out rates
    - rinse water usage
    - material consumption
    - plant operating times
- Industry-reported data from questionnaires
- Design water pollution control systems based on chemical treatment technology, the prevailing present practice in the industry, and derive the sludge production rates
- Derive rates of waste generation during production.

One of the points worthy of discussion is the waste load produced with each regeneration of the electroless nickel bath. Electroless nickel plating was included as representative of the industry and it was further assumed that the bath would be regenerated in-house. Because of the large quantity of salts precipitated from the large volume of bath necessary for a high rate of production, these process wastes are identified separately.

The data developed regarding waste generation by model plants, and the state and EPA regional distribution of job shops, were used to calculate the quantity of waste destined for land disposal.

The number of job shops in a given state was aggregated into three size ranges corresponding to the model plants. The waste generation rates of each of the model plants were then multiplied by the number of plants in each size range for each of the states.

The waste generation rates of the model plants are based on the proposed U.S. EPA effluent limitations and guidelines which are to apply in 1977 and 1983 and on the estimated production for those years. To establish estimates for 1975, various factors have been taken into consideration. The adjustment of the basic 1977 model plant waste quantities to 1975 required an allowance for those plants not currently producing water pollution control sludges. To simulate this situation, pertinent information was gathered from state and local agencies in order to determine the degree and incidence of pollution control currently existing. Such estimates were developed to the best degree possible for areas (states) containing the large numbers of electroplating job shops. A review of the industry responses showed that about 35 percent of the reporting plants produced water pollution control sludge in 1975.

Economic data indicate that the industry will not undergo any major expansion or reduction. Consequently, the wastes generated from electroplating and metal finishing processes other than water pollution control sludges are projected as unchanged between 1975 and 1977. Thus, it is concluded that the significant differences in waste quantities between 1977 and 1975 will be in water pollution control sludge quantities.

The estimated quantities of waste destined for land disposal by the electroplating and metal finishing industry (job shops) for each state, EPA Region, and nationally during 1975 are shown in Table 4. The major portion of the wastes, 54 percent, are process wastes. The water pollution

TABLE 4. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1975

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total**	Total Hazardous Constituents in Water Pollution Control Sludges***
Region I						
Massachusetts	847.77	1,814.25	251.35	541.13	3,454.50	338.07
Connecticut	926.66	1,979.51	254.96	526.50	3,687.63	376.51
Rhode Island	1,039.85	2,148.49	280.15	1,126.13	4,594.62	416.04
New Hampshire	15.96	36.33	6.15	0.00	58.44	6.09
Maine	38.99	82.80	8.31	14.63	144.73	16.69
Vermont	22.89	49.53	7.69	14.63	94.74	8.84
Region I Total	2,892.12	6,110.91	808.61	2,223.02	12,034.66	1,162.24
Region II						
New Jersey	879.55	1,912.34	274.90	394.88	3,461.67	349.04
New York	1,667.96	3,555.91	450.86	965.25	6,639.98	679.84
Region II Total	2,547.51	5,468.25	725.76	1,360.13	10,101.65	1,028.88
Region III						
Delaware	5.32	12.11	2.05	0.00	19.48	2.04
Maryland	83.02	183.83	29.73	29.25	325.83	31.93
Pennsylvania	960.68	2,062.10	270.33	497.25	3,790.36	389.26
Virginia	52.85	109.20	11.39	43.88	217.32	22.21
West Virginia	148.26	315.28	39.18	87.75	590.47	60.66
Region III Total	1,250.13	2,682.52	352.68	658.13	4,943.46	506.10
Region IV						
Alabama	176.33	379.98	54.45	102.38	713.14	69.81
Florida	203.42	449.37	68.28	58.50	779.57	79.81
Georgia	141.47	299.02	32.11	73.13	545.73	59.64
Kentucky	139.23	292.15	34.57	102.38	568.33	57.36
Mississippi	65.59	143.35	18.56	14.63	242.13	26.85
North Carolina	213.22	452.85	59.69	146.25	872.01	85.94
South Carolina	111.51	239.35	28.41	43.88	423.15	46.30
Tennessee	193.41	408.56	56.51	160.88	819.36	76.80
Region IV Total	1,244.18	2,664.63	352.58	702.03	4,963.42	502.51
Region V						
Illinois	1,706.60	3,649.18	455.78	877.50	6,689.06	698.96
Indiana	664.44	1,425.42	180.91	321.75	2,592.52	271.38
Michigan	2,827.16	5,978.98	753.67	1,959.75	11,519.56	1,150.53
Minnesota	319.41	680.09	86.05	190.13	1,275.68	130.19
Ohio	1,953.28	4,196.86	552.96	994.50	7,697.60	790.69
Wisconsin	374.50	796.16	94.98	204.75	1,470.39	154.72
Region V Total	7,845.39	16,726.69	2,124.35	4,548.38	31,244.81	3,196.47

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* These dry weights can be converted to wet weights by multiplying by the following factors: WPCS - 20; PW - 1; DS - 1; ENW - 2.

** Note: Total Industry Wastes = Potentially Hazardous Wastes.

*** Estimated compositional information is not available for the other classes of potentially hazardous wastes.

TABLE 4. (Continued)

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total**	Total Hazardous Constituents in Water Pollution Control Sludges***
Region VI						
Arkansas	63.49	133.42	15.49	43.88	256.28	26.28
Louisiana	17.57	37.42	5.64	14.63	75.26	6.82
New Mexico	38.85	85.86	13.84	14.63	153.18	14.94
Oklahoma	106.19	227.24	26.36	43.88	403.67	44.26
Texas	643.02	1,380.04	178.24	321.75	2,523.05	261.53
Region VI Total	869.12	1,863.98	239.57	438.77	3,411.44	353.83
Region VII						
Iowa	229.95	491.90	58.36	102.38	882.58	95.34
Kansas	272.93	579.60	58.17	102.38	1,013.08	116.83
Missouri	488.25	1,042.38	120.93	219.38	1,870.94	203.31
Nebraska	40.46	86.95	13.33	29.25	169.99	15.68
Region VII Total	1,031.59	2,200.83	250.79	453.39	3,936.59	431.16
Region VIII						
Colorado	252.98	538.37	60.52	117.00	968.87	105.95
Montana	5.32	12.11	2.05	0.00	19.48	2.04
North Dakota	0.00	0.00	0.00	0.00	0.00	0.00
South Dakota	5.32	12.11	2.05	0.00	19.48	2.04
Utah	44.17	97.97	15.89	14.63	172.66	16.99
Wyoming	0.00	0.00	0.00	0.00	0.00	0.00
Region VIII Total	307.79	660.56	80.51	131.63	1,180.49	127.02
Region IX						
Arizona	135.87	293.03	41.12	73.13	543.15	54.15
California	1,267.35	2,708.04	349.21	716.63	5,041.23	514.83
Hawaii	5.32	12.11	2.05	0.00	19.48	2.04
Nevada	21.28	48.44	8.20	0.00	77.92	8.12
Region IX Total	1,429.82	3,061.62	400.58	789.76	5,681.78	579.14
Region X						
Alaska	0.00	0.00	0.00	0.00	0.00	0.00
Idaho	15.96	36.33	6.15	0.00	58.44	6.09
Oregon	150.50	322.15	36.72	58.50	567.87	62.98
Washington	155.40	343.44	55.36	58.50	612.70	59.78
Region X Total	321.86	701.92	98.23	117.00	1,239.01	128.85
Total U. S.	19,739.51	42,141.91	5,433.66	11,422.24	78,737.32	8,016.20

** Note: Total Industry Wastes = Potentially Hazardous Wastes.

*** Estimated compositional information is not available for the other classes of potentially hazardous wastes.

control sludges are 25 percent of the total, followed by electroless nickel plating wastes at 15 percent, and 6 percent for degreaser sludges. The fact that only an estimated 35 percent of the total job shops are producing water pollution control sludges in 1975 is the reason that the general wastes associated with all metal finishing operations account for more than half of the total wastes.

The estimated quantities of potentially hazardous waste to be destined for land disposal by the electroplating and metal finishing industry (job shops) in 1977 are given in Table 5. The 115,396 metric tons (dry weight) represents an almost 50 percent increase in waste quantity over 1975, all of it coming from the additional load of water pollution control sludge. Forty-nine percent of the 1977 total waste is water pollution control sludge, while process wastes amount to only approximately 37 percent. Electroless nickel wastes and degreaser sludge constitute 10 and 4 percent of the waste, respectively.

Waste projections for 1983 are based on a study by the U.S. EPA's Effluent Guidelines Division.* The responses obtained from the job shops for this study did not provide projections to 1983, naming the proposed 1983 zero-discharge limitation of plant effluents as the reason for the inability to determine or predict water pollution control sludge loads. Necessary changes in treatment practices are another reason given. The above cited report projects an industry growth of 31 percent from 1977 to 1983. Consequently, 1983 estimated land-destined waste quantity projections were calculated by multiplying the 1977 waste quantity estimate by the factor 1.31.

The data for each state and EPA Region and nationally are summarized in Table 6 in terms of the four designated waste categories. The total estimated quantity of waste destined for land disposal in 1983 is 151,166 metric tons. Almost 40 percent of this waste will be from plants located in Region V and more than 67 percent will be from plants located in Regions I, II, and V.

A summary of all the wastes destined for land disposal by the electroplating and metal finishing job shop industry for 1975, 1977, and 1983 is given in Table 7 in order to compare waste loads and ratios of waste categories from the job shops represented by one of these model plants:

Small with an average of 16 employees in plating.
Medium with an average of 38 employees in plating.
Large with an average of 87 employees in plating.

The 38-employee model plant (or medium-sized job shop) represents the group of plants with the greatest waste load. Water pollution control sludges are the most important contributors to that waste load, which contains large amounts of hazardous metal hydroxides and soluble salts.

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* Economic Analysis of Effluent Guidelines - Metal Finishing Industry. Report No. EPA 230/1-74-032, Sept. 1974, p. VI-8.

TABLE 5. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1977

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total**	Total Hazardous Constituents in Water Pollution Control Sludges***
Region I						
Massachusetts	2,422.20	1,814.25	251.35	541.13	5,028.93	975.89
Connecticut	2,647.60	1,979.51	254.96	526.50	5,408.57	1,075.70
Rhode Island	2,971.00	2,148.49	280.15	1,126.13	6,525.77	1,188.67
New Hampshire	45.60	36.33	6.15	0.00	88.08	17.41
Maine	111.40	82.80	8.31	14.63	217.14	47.68
Vermont	65.40	49.53	7.69	14.63	137.25	25.28
Region I Total	8,263.20	6,110.91	808.61	2,223.02	17,405.74	3,330.63
Region II						
New Jersey	2,513.00	1,912.34	274.90	394.88	5,095.12	997.25
New York	4,765.60	3,555.91	450.86	965.25	9,737.62	1,942.43
Region II Total	7,278.60	5,468.25	725.76	1,360.13	14,832.74	2,939.68
Region III						
Delaware	15.20	12.11	2.05	0.00	29.36	5.80
Maryland	237.20	183.83	29.73	29.25	480.01	91.21
Pennsylvania	2,744.80	2,062.10	270.33	497.25	5,574.48	1,112.14
Virginia	151.00	109.20	11.39	43.88	315.47	63.44
West Virginia	423.60	315.28	39.18	87.75	865.81	173.33
Region III Total	3,571.80	2,682.52	352.68	658.13	7,265.13	1,445.92
Region IV						
Alabama	503.80	379.98	54.45	102.38	1,040.61	199.46
Florida	581.20	449.37	68.28	58.50	1,157.35	228.02
Georgia	404.20	299.02	32.11	73.13	808.46	170.44
Kentucky	397.80	292.15	34.57	102.38	826.90	163.83
Mississippi	187.40	143.35	18.56	14.63	363.94	76.69
North Carolina	609.20	452.85	59.69	146.25	1,267.99	245.54
South Carolina	318.60	239.35	28.41	43.88	630.24	132.26
Tennessee	552.60	408.56	56.51	160.88	1,178.55	219.43
Region IV Total	3,554.80	2,664.63	352.58	702.03	7,274.04	1,435.67
Region V						
Illinois	4,876.00	3,649.18	455.78	877.50	9,858.46	1,997.03
Indiana	1,898.40	1,425.42	180.91	321.75	3,826.48	775.41
Michigan	8,077.60	5,978.98	753.67	1,959.75	16,770.00	3,287.21
Minnesota	912.60	680.09	86.05	190.13	1,868.87	372.00
Ohio	5,580.80	4,196.86	552.96	994.50	11,325.12	2,259.14
Wisconsin	1,070.00	796.16	94.98	204.75	2,165.89	442.04
Region V Total	22,415.40	16,726.69	2,124.35	4,548.38	45,814.82	9,132.83

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* These dry weights can be converted to wet weights by multiplying by the following factors: WPCS - 20; PW - 1; DS - 1; ENW - 2.

** Note: Total Industry Wastes = Potentially Hazardous Wastes.

*** Estimated compositional information is not available for the other classes of potentially hazardous wastes.

TABLE 5. (Continued)

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total**	Total Hazardous Constituents in Water Pollution Control Sludges***
Region VI						
Arkansas	181.40	133.42	15.49	43.88	374.19	75.06
Louisiana	50.20	37.42	5.64	14.63	107.89	19.50
New Mexico	111.00	85.86	13.84	14.63	225.33	42.70
Oklahoma	303.40	227.24	26.36	43.88	600.88	126.45
Texas	1,837.20	1,380.04	178.24	321.75	3,717.23	747.21
Region VI Total	2,483.20	1,863.98	239.57	438.77	5,025.52	1,010.92
Region VII						
Iowa	657.00	491.90	58.36	102.38	1,309.64	272.42
Kansas	779.80	579.60	58.17	102.38	1,519.95	333.76
Missouri	1,395.00	1,042.38	120.93	219.38	2,777.69	580.90
Nebraska	115.60	86.95	13.33	29.25	245.13	44.78
Region VII Total	2,947.40	2,200.83	250.79	453.39	5,852.41	1,231.86
Region VIII						
Colorado	722.80	538.37	60.52	117.00	1,438.69	302.69
Montana	15.20	12.11	2.05	0.00	29.36	5.80
North Dakota	0.00	0.00	0.00	0.00	0.00	0.00
South Dakota	15.20	12.11	2.05	0.00	29.36	5.80
Utah	126.20	97.97	15.89	14.63	254.69	48.50
Wyoming	0.00	0.00	0.00	0.00	0.00	0.00
Region VIII Total	879.40	660.56	80.51	131.63	1,752.10	362.79
Region IX						
Arizona	388.20	293.03	41.12	73.13	795.48	154.68
California	3,621.00	2,708.04	349.21	716.63	7,394.88	1,470.91
Hawaii	15.20	12.11	2.05	0.00	29.36	5.80
Nevada	60.80	48.44	8.20	0.00	117.44	23.21
Region IX Total	4,085.20	3,061.62	400.58	789.76	8,337.16	1,654.60
Region X						
Alaska	0.00	0.00	0.00	0.00	0.00	0.00
Idaho	45.60	36.33	6.15	0.00	88.08	17.41
Oregon	430.00	322.15	36.72	58.50	847.37	179.94
Washington	444.00	343.44	55.36	58.50	901.30	170.83
Region X Total	919.60	701.92	98.23	117.00	1,836.75	368.18
Total U. S.	56,398.60	42,141.91	5,433.66	11,422.24	115,396.41	22,913.08

** Note: Total Industry Wastes = Potentially Hazardous Wastes.

*** Estimated compositional information is not available for the other classes of potentially hazardous wastes.

TABLE 6. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1983

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total**	Total Hazardous Constituents in Water Pollution Control Sludges***
Region I						
Massachusetts	3,173.08	2,376.67	329.27	708.87	6,587.89	1,265.32
Connecticut	3,468.36	2,593.16	334.00	689.72	7,085.24	1,409.19
Rhode Island	3,892.01	2,814.52	367.00	1,475.22	8,548.75	1,557.15
New Hampshire	59.74	47.59	8.06	0.00	115.39	22.79
Maine	145.93	108.47	10.89	19.16	284.45	62.46
Vermont	85.67	64.88	10.07	19.16	179.78	33.13
Region I Total	10,824.79	8,005.29	1,059.29	2,912.13	22,801.50	4,350.04
Region II						
New Jersey	3,292.03	2,505.17	360.12	517.29	6,674.61	1,306.38
New York	6,242.94	4,658.21	590.63	1,364.48	12,856.26	2,544.58
Region II Total	9,534.97	7,163.38	950.75	1,881.77	19,530.87	3,850.96
Region III						
Delaware	19.91	15.86	2.69	0.00	38.46	7.60
Maryland	310.73	240.82	38.95	38.32	628.82	119.50
Pennsylvania	3,595.69	2,701.35	354.13	651.40	7,302.57	1,456.91
Virginia	197.81	143.05	14.92	57.48	413.26	83.14
West Virginia	554.92	413.02	51.33	114.95	1,134.22	227.08
Region III Total	4,679.06	3,514.10	462.02	862.15	9,517.33	1,894.23
Region IV						
Alabama	659.98	497.77	71.33	134.11	1,363.19	261.31
Florida	761.37	588.67	89.45	76.64	1,516.13	298.71
Georgia	529.50	391.72	42.06	95.79	1,059.07	223.26
Kentucky	521.12	382.72	45.29	134.11	1,083.24	214.60
Mississippi	245.49	187.79	24.31	19.16	476.75	100.56
North Carolina	798.05	593.23	78.19	191.59	1,661.06	321.64
South Carolina	417.37	313.55	37.22	57.48	825.62	173.26
Tennessee	723.91	535.21	74.03	210.75	1,543.90	287.45
Region IV Total	4,656.79	3,490.66	461.88	919.63	9,528.96	1,880.79
Region V						
Illinois	6,387.56	4,780.43	597.07	1,149.53	12,914.59	2,616.13
Indiana	2,486.90	1,867.30	236.99	421.49	5,012.68	1,015.78
Michigan	10,581.66	7,832.46	987.31	2,567.27	21,968.70	4,306.24
Minnesota	1,195.51	890.92	112.73	249.06	2,448.22	487.30
Ohio	7,310.85	5,497.89	724.38	1,302.80	14,835.92	3,959.43
Wisconsin	1,401.70	1,042.97	124.42	268.22	2,837.31	579.05
Region V Total	29,364.18	21,911.97	2,782.90	5,958.37	60,017.42	11,963.93

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* These dry weights can be converted to wet weights by multiplying by the following factors: WPCS - 20; PW - 1; DS - 1; ENW - 2.

** Note: Total Industry Wastes = Potentially Hazardous Wastes.

*** Estimated compositional information is not available for the other classes of potentially hazardous wastes.

TABLE 6. (Continued)

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total**	Total Hazardous Constituents in Water Pollution Control Sludges***
Region VI						
Arkansas	237.63	174.78	20.29	57.48	490.18	98.36
Louisiana	65.76	49.02	7.39	19.16	141.33	25.53
New Mexico	145.41	112.48	18.13	19.16	295.18	55.94
Oklahoma	397.45	297.68	34.53	57.48	787.14	151.64
Texas	2,406.73	1,807.85	233.49	421.49	4,869.56	960.85
Region VI Total	3,252.98	2,441.81	313.83	574.77	6,583.39	1,324.32
Region VII						
Iowa	860.67	644.39	76.45	134.11	1,715.62	356.87
Kansas	1,021.54	759.28	76.20	134.11	1,991.13	437.23
Missouri	1,827.45	1,365.52	158.42	287.38	3,638.77	760.99
Nebraska	151.44	113.90	17.46	38.32	321.12	58.69
Region VIITotal	3,861.10	2,883.09	328.53	593.92	7,666.64	1,613.78
Region VIII						
Colorado	946.87	705.26	79.28	153.27	1,884.68	396.51
Montana	19.91	15.86	2.69	0.00	38.46	7.60
North Dakota	0.00	0.00	0.00	0.00	0.00	0.00
South Dakota	19.91	15.86	2.69	0.00	38.46	7.60
Utah	165.32	128.34	20.82	19.16	333.64	63.56
Wyoming	0.00	0.00	0.00	0.00	0.00	0.00
Region VIII Total	1,152.01	865.32	105.48	172.43	2,295.24	475.27
Region IX						
Arizona	508.54	383.87	53.87	95.79	1,042.07	202.64
California	4,743.51	3,547.53	457.47	938.78	9,687.29	1,826.88
Hawaii	19.91	15.86	2.69	0.00	38.46	7.60
Nevada	79.65	63.46	10.74	0.00	153.85	30.42
Region IX Total	5,351.61	4,010.72	524.77	1,034.57	10,921.67	2,067.54
Region X						
Alaska	0.00	0.00	0.00	0.00	0.00	0.00
Idaho	59.74	47.59	8.06	0.00	115.39	22.79
Oregon	563.30	422.02	48.10	76.64	1,110.06	235.74
Washington	581.64	449.91	72.52	76.64	1,180.71	223.80
Region X Total	1,204.68	919.52	128.68	153.28	2,406.16	482.33
Total U. S.	73,882.17	55,205.86	7,118.13	15,063.02	151,269.18	29,903.19

** Note: Total Industry Wastes = Potentially Hazardous Wastes.

*** Estimated compositional information is not available for the other classes of potentially hazardous wastes.

TABLE 7. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT

	Model Plants			Waste Categories						
Year	Small(1) 16 Employees	Medium(2) 38 Employees	Large(3) 87 Employees	Water Pollution Control Sludge (WPCS)	Process Wastes (PW)	Degreaser Sludge (DS)	Subtotal(4)	Electroless Nickel Waste (ENW)	Total(5)*	Total Potentially Hazardous Constituents in Water Pollution Control Sludges
1975	23,629.36	30,787.80	24,537.48	19,739.51	42,141.91	5,433.66	67,315.08	11,422.24	78,737.32	8,016.20
1977	35,613.86	43,345.80	36,752.28	56,398.60	42,141.91	5,433.66	103,974.17	11,422.24	115,396.41	22,913.08
1983	46,654.15	56,783.00	48,145.49	73,882.17	55,205.86	7,118.13	136,206.16	15,063.02	151,269.18	29,903.19

(1) Representative of 1,213 job shops with from 5 to 25 employees in plating and a production of 1,440 m^2/day.
(2) Representative of 552 job shops with from 26 to 50 employees in plating and a production of 3,400 m^2/day.
(3) Representative of 232 job shops with more than 50 employees in plating and a production of 6,960 m^2/day.
(4) Combined WPCS, PW, and DS wastes.
(5) Refer to footnotes for Tables 4, 5, and 6 for appropriate factors to convert dry weights to wet weights for 1975, 1977, and 1983 estimates.

* Note: Total Industry Wastes = Potentially Hazardous Wastes.

Treatment and Disposal Technology

The current prevalent practice for the disposal of the four classes of potentially hazardous wastes from the electroplating and meta finishing industry is the use of a landfill. The landfill operation may range from an open dump to a covered landfill, and includes the use of abandoned mines and quarries. Approximately 60 to 70 percent of the pla reporting use off-site disposal for their wastes. Although a few plants may employ safeguards such as chemical fixation, solidification, etc., t prevalent practice generally utilizes the simplest possible disposal techniques acceptable to local authorities. This generalization holds true whether the disposal is carried out by the operators of the electroplatin facility or by a private contractor.

The three levels of treatment and disposal technology defined i the disposal of wastes from job shops are as follows:

Level I - Prevalent practice
Level II - Best technology currently used
Level III - Practice considered environmentally adequate.

The broad average treatment and disposal practice for wastes destined for land disposal, defined as Level I, is discussed below for th following four major waste streams: (1) water pollution control sludge, (2) process wastes, (3) solvent sludges, and (4) electroless nickel waste

The prevalent treatment/disposal practice for water pollution control sludge is concentration to 1-5 percent solids content, followed by land disposal. The waste is an aqueous slurry of metal hydroxides. The Level I technology is inadequate to provide acceptable health and environmental protection, primarily because of the potential contamination of ground water and surface water supplies possible with this method of dispo

In some instances, concentrated inorganic solutions (precious me baths, and selected, rich, noncontaminated solutions of chromium, nickel, or copper) are reclaimed and no waste is generated. In other cases, the spent concentrated solutions are treated in the water pollution control open facility, and the metals become a part of the water pollution control sludges.

The prevalent treatment/disposal practice for process wastes is municipal landfill disposal. Process wastes are composed of solids and semi-solids contaminated with toxic metals from the metal-finishing operati These wastes are not normally regarded as hazardous by the industry and ar therefore disposed of with nonhazardous plant trash in municipal landfills. This disposal method is not considered adequate for health and environment protection because of the potential for ground water and surface water contamination.

The solvents used in degreasing operations become contaminated with toxic metals. These metals are removed in the reclamation operations and transferred to a solvent sludge. The prevalent disposal practice for solvent sludges is simple land disposal with the process wastes or water pollution control sludges. This practice is considered inadequate because of potential ground and surface water contamination.

Wastes also are generated during the regeneration of electroless nickel baths. Although not specifically included as a component of the wastes produced by plants responding to inquiries made during this study, they are produced by facilities which include electroless plating operations. Most of the successful regeneration operations are based on the chemical precipitation of the phosphite ion. These precipitated materials usually are taken to a landfill for disposal. This is considered prevalent practice for this class of wastes.

The best current (Level II) treatment/disposal practice for water pollution control sludge involves (1) solids concentration, (2) dewatering to greater than or equal to 20 percent solids cake, and (3) disposal in a sanitary landfill approved by a state or local authority for receiving wastes of this nature. The additional safeguards above the Level I technology include the dewatering operation, which produces a high-solids (increase from 1-6 to 20 percent solids), lower volume, sludge cake. In addition to easier, more economical disposal, the higher-solids cake has increased resistance to metal hydroxide resolubilization and mobilization to toxic metal ions. The most important additional safeguard, however, is the change from simple land disposal (surface burial, open dumps, municipal landfills, etc.) in Level I to an approved sanitary landfill for Level II. An approved sanitary landfill is a disposal site where extraordinary precautions have been taken in the areas of site selection and leachate control monitoring. Disposal of water pollution control sludges in such a disposal site is considered adequate for short-term disposal. Long-term protection, however, cannot be assured since surface runoff and rain water can still percolate through the disposal area, leading to leachate formation. If the impervious barriers placed in the bottom of the landfill should become ruptured, break, or otherwise fail, no means are available to collect the leachate for treatment or excavate the problem hazardous wastes.

The best current treatment/disposal practice for the contaminated solid and semi-solid process wastes is disposal in an approved sanitary landfill. As noted above, an approved sanitary landfill is considered adequate for short-term disposal. However, because such facilities do not provide the means for leachate collection and treatment, waste segregation and mapping, long-term protection of the environment cannot be assured.

The best treatment/disposal practice for solvent sludges and for electroless nickel wastes is disposal in an approved sanitary landfill. This disposal method is considered adequate for short-term disposal. Long-term protection, however, cannot be assured because of the lack of facilities for leachate collection and treatment, waste segregation and mapping.

The technology identified as environmentally adequate (Level III) in this study consists principally of the present best technology described with some modifications in the preparation and operation of the approved sanitary landfills.

The selected site should undergo extensive geological evaluation for hydraulic connections to ground and surface waters. Subsoil characterizations should also be made to determine where there is the need for impervious liners to prevent horizontal and vertical migration of hazardous constituents. A characterization of surrounding ground water and surface waters before the site is activated is required. In addition, the site should be operated in such a fashion as to permit disposal of similar materials in separated and isolated cells. The location of each cell should be identified and mapped and its contents recorded. Facilities for leachate collection are essential for liquid, low-solids slurries and/or soluble metal waste disposal. These safeguards would permit easy isolation of problem areas and the removal of wastes to remedy the problem. It would also permit the excavation for recovery of such wastes for resource reclamation. Since long-term physical protection of the environment is the goal, surveillance and monitoring of the disposal sites, including regular analysis of ground and surface waters for changes in background levels, are necessary. There are several designs in operation or under consideration to facilitate leachate collection (for surveillance and treatment, if necessary) from potentially hazardous waste disposal sites. Leachate may be collected by sumps at the bottom of each disposal cell, infiltration piping along trenches in the disposal site, a perimeter trench to catch horizontal migration of liquid wastes, diversion ditches to collect and transport runoff and leachate, and ground water wells. Once the leachate is collected, it is neutralized with lime to precipitate metal hydroxides. The dewatered solids can be returned to the disposal site and the effluent can be discharged to the sewer.

Cost Analysis

For purpose of the cost analysis of Level I technology for the model plants, a water pollution control (WPC) sludge containing 5 percent solids was assumed to have been produced by the use of clarifiers and/or settling tanks. The production of the 5 percent solids sludge was considered to have been part of the waste water treatment operation and its costs. The principal item of equipment required for this sludge at the electroplating plant is the storage vessel.

For Level II and III technologies for the model plants, the WPC stream underflow from a clarifier containing 2 percent solids was assumed to be dewatered to a 20 percent sludge with a centrifuge. The production of the 2 percent solids underflow was considered to be part of the waste water treatment operation and its costs. The principal item of cost to the electroplater is a centrifuge and associated pipes, pumps, and vessels.

Contractor hauling, treatment, and off-site landfill disposal of electroplating and metal finishing wastes was assumed to be employed at the three model plants for the three technology levels. Such contractor hauling and disposal of wastes had been identified as the prevalent practice in the industry. The wastes from all four streams (i.e., water pollution control (WPC) sludge, process wastes, degreaser solvent sludge, and electroless Ni-bath treatment sludge) were considered potentially hazardous and were assumed to be handled and disposed of in the same manner.

The contractor charges for combined hauling, treatment, and disposal of the wastes were developed as shown below:

Technology Level	Disposal	Contractor Waste Hauling, Treatment, and Disposal Charge*
I	Land Burial	\$34.30/MT (\$13.90/1000 m^2)**
II	Approved Landfill	\$41.95/MT (\$ 5.00/1000 m^2)**
III	Secured Landfill	\$68.45/MT (\$ 8.15/1000 m^2)**

---

* Costs are in dollars per metric ton of gross weight of all combined categories of wastes.

** Cost based on area of workpieces processed, i.e., production.

The total costs for treatment and disposal, at the three technology levels, of WPC sludges, process wastes, solvent sludges, and electroless Ni sludges for all U.S. job shops for 1975 are shown on an individual-stream and combined-stream basis in Table 8.

The costs of treatment and disposal for Level I technology ranged from about \$56/MT (dry weight) for process wastes to about \$820/MT (dry weight) for water pollution control sludges. For Level II technology the costs ranged from about \$66/MT (dry weight) for process wastes to about \$477/MT (dry weight) for water pollution control sludges. For Level III technology the cost range was about \$82/MT (dry weight) to \$588/MT (dry weight), respectively.

It is readily apparent from Table 8 that the costs for treatment and disposal of wastes at Technology Level I are significantly higher than those for Levels II and III for all the model plants. The reason for this apparent discrepancy is the fact that Level I technology involves the treatment and disposal of WPC sludge containing 5 percent solids as opposed to WPC sludge containing 20 percent solids for Technology Levels II and III. Dewatering the sludge from 5 to 20 percent solids results in a 4.4-fold reduction in the volume of sludge, and accounts for the significantly lower overall treatment and disposal costs for Levels II and III. As expected, the waste treatment and disposal costs for Level II technology were lower than those for Level III technology, with the cost difference being accounted for by the higher contractor charge for Level III landfill disposal.

Larger volumes of sludge are generated in the water pollution control (WPC) stream in comparison with the other waste streams because of the large amounts of water associated with the WPC sludges. For this reason the costs for the treatment and disposal of the WPC sludges ranged from about 80 to 93 percent of the costs for the combined waste streams irrespective of the plant size and treatment technology levels. Accordingly, the use of in-process controls, such as save rinses, or the use of techniques such as evaporation, reverse osmosis, or ion-exchange for the recovery of drag out chemicals, offers the most promise for reducing the quantity of sludge and thereby cutting the costs related to the treatment and disposal of WPC sludges at all treatment levels.

TABLE 8. NATIONAL COSTS FOR THE TREATMENT AND DISPOSAL OF ELECTROPLATING AND METAL FINISHING WASTES AT DIFFERENT TECHNOLOGY LEVELS[(a)]

Waste Stream[(b)]	Annual Amount of Waste Projected Nationally by Weight,[(c)] metric tons/yr	National Costs at Different Technology Levels for Different Size Category Plants I $1000/yr	II $1000/yr	III $1000/yr
	1975 Total U.S. Costs (Combined Plant Categories)			
WPC Sludge	19,792	16,247	9,437	11,634
Process Wastes	42,251	2,385	2,788	3,459
Solvent Sludge	5,445	865	919	1,029
Electroless-Ni Sludge	11,466	1,131	1,362	1,860
Combined Streams	78,954	20,628	14,506	17,982

(a) All costs are expressed in terms of December 1973 dollars.

(b) WPC = Water Pollution Control.

(c) The weights shown for the WPC sludge, process wastes, and electroless-Ni sludge are on a dry-weight basis. The weights of the solvent sludge are expressed on an as-is basis. The amounts of water pollution control (WPC) sludges generated in 1975 were taken as equivalent to 35 percent of the WPC wastes to be generated in 1977 for each plant size category. The quantity of process wastes, solvent sludges, and electroless-Ni sludges for 1975 were the same as those projected for 1977.

The value added by manufacturing in the electroplating and metal finishing job shops was $749,100,000 in 1972. Assuming an inflation rate of 6 percent to convert the 1972 value to December 1973, dollars, the value-added figure becomes $794,000,000. The ratios of waste management costs at different treatment and disposal technology levels to the value-added statistic for the industry range from 1.83 to 2.60 percent for 1975 (Table 9). Thus, the waste treatment and disposal cost constitutes a relatively small part of the overall production costs in the electroplating and metal finishing industry.

Captive Shops

The captive shop is an electroplating or metal finishing operation included in a manufacturing operation, and which works on parts connected only with that manufacturing operation. The fact that this category of shops is a part of some manufacturing operation results in a situation where the captive shops are not discernible in U.S. Bureau of Census statistics. In the Census statistics, the various manufacturing operations in the U.S. are reported in terms of the Standard Industrial Classification (SIC) of the final product. In many cases, the contributing captive electroplating operation remains unidentified. Thus, there are no reliable data on the number or size of captive shops.

A preliminary assessment of the potentially hazardous waste practices of the captive shop segment of the metal finishing industries has been completed. This assessment consisted of:

(1) The characterization of this industrial segment
(2) The characterization of its potentially hazardous wastes
(3) The identification of the treatment and disposal technology which it practices
(4) The estimation of costs associated with treatment and disposal of these wastes.

Information related to the factors listed above was sought through:

(1) Questionnaires mailed to more than 7,000 companies through the National Association of Metal Finishers
(2) Telephone conversations with personnel associated with metal finishing facilities and with treatment and disposal contractors
(3) Visits to captive shops and to treatment and disposal facilities
(4) In-depth studies at four complex plants.

No accurate data could be obtained during this study on the number of plants, the size of these plants, or their specific geographical location. Only a small number (53) of captive shops provided information pertinent to the study. Since estimates of the total number range from

TABLE 9. COMPARISON OF WASTE TREATMENT AND DISPOSAL COSTS TO VALUE-ADDED STATISTIC FOR THE ELECTROPLATING AND METAL FINISHING INDUSTRY FOR DIFFERENT TREATMENT TECHNOLOGY LEVELS[(a)]

Year	Annual Value Added Statistic, dollars	National Waste Treatment and Disposal cost, dollars/yr	Treatment Technology Level	Ratio of Waste Treatment & Disposal Cost to Value-Added Statistic Expressed as a percent
1975[(a)]	794,000,000	20,628,000	I	2.60
	794,000,000	14,506,000	II	1.83
	794,000,000	17,982,000	III	2.24

(a) Costs are expressed in terms of constant December, 1973 dollars.

2,000 to 22,000, this is an extremely small sample of the industry. The average size of the shops providing data was 53 employees. This number is the number of employees associated with plating and metal finishing. Some captive shops were in manufacturing plants with considerably (up to 2000) more total employees.

Although the specific geographical locations of all of the captive shops are not known, these facilities usually are associated with manufacturing complexes of various types. It is believed that the geographical distribution of captive shops follows both that of heavy manufacturing industries and that of the job shops. Thus, there are heavy concentrations of captive shops in the north and middle Atlantic states, in the north central states, and in California, or in EPA Regions I, II, III, V, and IX.

Potentially hazardous waste streams generated by captive shops have been categorized as follows:

(1) Water pollution control sludges
(2) Process wastes
(3) Degreaser sludges
(4) Electroless nickel wastes.

The principal potentially hazardous constituents found in these wastes are heavy metals and residual organic materials. The rationale for the classification of these materials as potentially hazardous is presented in the previous discussion on the job shop segment of the industry.

Because of the extremely limited data acquired through direct means, information on the quantities of wastes generated has been obtained by using model plant calculations prepared for the job shop segment of this industry. On the basis of those calculations and the assumptions that the average captive shop employes 53 persons, that there are 12,000 of these average shops in the U.S., and that they all will meet effluent limitation guidelines requirements in 1977 and 1983, preliminary projections of potentially hazardous wastes destined for land disposal on a national basis were made as follows:

Year	Total Wastes Destined for Land Disposal	
	Dry, metric tons	Wet, metric tons
1975	830,000	4,810,000
1977	1,200,000	3,700,000
1983	1,600,000	4,800,000

The three levels of treatment and disposal technology defined for the disposal of wastes from captive shops are as follows:

Level I - Prevalent practice: simple landfill

Level II - Best technology currently used: dewatering of sludges, with disposal in an approved landfill

Level III - Practice considered environmentally adequate: dewatering of sludges, with disposal in a secured landfill.

It is estimated that the total annual operating costs for waste treatment and disposal on a national basis for these levels are as follows:

Level I	$516,000,000
Level II	$324,000,000
Level III	$432,000,000

The lesser costs for Levels II and III occur because the total weight of water pollution control sludges is reduced by a factor of four through dewatering.

In conclusion, it must be reemphasized that the projections of waste quantities and treatment and disposal costs presented herein are based on extremely sparse data. They may be in error by an order of magnitude because of the lack of information from a representative sample of the industry. Therefore they should be used discretely and only as a preliminary indication of the levels which ultimately may be determined if a more comprehensive future study is undertaken.

Further details on electroplating captive shops may be obtained from an unpublished report maintained in OSW files.

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I. INDUSTRY CHARACTERIZATION

INTRODUCTION

Practically all types of manufacturing involve electroplating and metal finishing operations. Two distinct types of facilities that do electroplating and metal finishing operations are recognized. One is job shops, which are independent companies doing work on materials owned by others. The second is captive shops which are part of a larger corporate organization and do work on materials owned by that organization. Job shops are the subject of the following discussion.

This section of this report contains information on the following characteristics of the electroplating and metal finishing job shop industry:

Products of the industry
Current economic status
Future trends and developments
Geographic distribution of plants
Distribution of plants by size
Distribution of plants by age
Distribution of plants by process

PRODUCTS OF THE INDUSTRY

As defined by the Department of Commerce: "The Plating and Polishing Industry includes establishments primarily engaged in all types of electroplating, plating, anodizing, coloring, and finishing metal, and formed products for the trade. Most of the work done in this industry is done on materials owned by others."(53) The electroplating industry utilizes chemical and electrochemical operations to effect an improvement in the surface properties of metals and other materials.

Thus the products of the industry are metallic coatings applied to metallic or nonmetallic products manufactured by others. Each product requires specific process sequences to obtain the desired physical, chemical, or aesthetic values. Table 1 summarizes the metal finishing operations and the metals most frequently deposited as coatings. The processes used to achieve these coatings on ferrous, nonferrous, and nonmetallic materials are described in the following section entitled "Generalized Process Description". The coating may consist of a single or of multiple electrodeposits. For example, automotive trim may be finished with successive coatings of copper-nickel-nickel-chromium which provides corrosion protection and is also decorative, or chromium only may be applied to steel as a wear resistant coating.

The manufacturing industries which are normally services by the electroplating and metal finishing establishments are SIC groups 34 (Fabri-

TABLE 1. DISTRIBUTION OF PLANTS BY PROCESS AND

			Metal Finishing Processes							
EPA Region and State	Number of Plants Reporting	Electro-plating	Electroless Plating	Anodizing	Chromating	Phosphating	Bright Dipping	Chemical Polishing	Dying
U.S. TOTAL	70	65	21	19	50	22	31	5	17
Region I	14	14	6	7	12	8	10	1	6
Massachusetts	5	5	1	2	3	2	3	0	2
Connecticut	6	6	5	3	6	4	4	0	1
Rhode Island	1	1	0	0	1	0	1	0	1
New Hampshire	0	–	–	–	–	–	–	–	–
Maine	2	2	0	2	2	2	2	1	2
Vermont	0	–	–	–	–	–	–	–	–
Region II	10	10	5	3	3	2	5	1	3
New Jersey	2	2	2	1	0	0	1	0	0
New York	8	8	3	2	3	2	4	1	3
Region III	5	4	0	2	4	1	1	0	0
Delaware	0	–	–	–	–	–	–	–	–
Maryland	2	2	0	1	1	1	0	0	0
Pennsylvania	3	2	0	1	3	0	1	0	0
Virginia	0	–	–	–	–	–	–	–	–
West Virginia	0	–	–	–	–	–	–	–	–
Region IV	3	3	0	1	2	1	2	1	1
Alabama	0	–	–	–	–	–	–	–	–
Florida	0	–	–	–	–	–	–	–	–
Georgia	0	–	–	–	–	–	–	–	–
Kentucky	0	–	–	–	–	–	–	–	–
Mississippi	1	1	0	0	1	0	1	0	0
North Carolina	0	–	–	–	–	–	–	–	–
South Carolina	1	1	0	0	0	0	0	0	0
Tennessee	1	1	0	1	1	1	1	1	1
Region V	22	20	3	2	12	6	6	0	3
Illinois	5	4	1	0	2	2	0	0	0
Indiana	0	–	–	–	–	–	–	–	–
Michigan	5	5	1	1	3	2	0	0	1
Minnesota	2	2	1	0	1	0	2	0	0
Ohio	7	7	0	1	5	1	4	0	2
Wisconsin	3	2	0	0	1	1	0	0	0
Region VI	2	2	1	1	1	1	1	0	1
Arkansas	0	–	–	–	–	–	–	–	–
Louisiana	0	–	–	–	–	–	–	–	–
New Mexico	0	–	–	–	–	–	–	–	–
Oklahoma	0	–	–	–	–	–	–	–	–
Texas	2	2	1	1	1	1	1	0	1
Region VII	1	1	1	1	1	0	1	0	1
Iowa	0	–	–	–	–	–	–	–	–
Kansas	0	–	–	–	–	–	–	–	–
Missouri	0	–	–	–	–	–	–	–	–
Nebraska	1	1	1	1	1	0	1	0	1
Region VIII	0	–	–	–	–	–	–	–	–
Colorado	0	–	–	–	–	–	–	–	–
Montana	0	–	–	–	–	–	–	–	–
North Dakota	0	–	–	–	–	–	–	–	–
South Dakota	0	–	–	–	–	–	–	–	–
Utah	0	–	–	–	–	–	–	–	–
Wyoming	0	–	–	–	–	–	–	–	–
Region IX	13	11	5	2	7	3	5	2	2
Arizona	0	–	–	–	–	–	–	–	–
California	13	11	5	2	7	3	5	2	2
Nevada	0	–	–	–	–	–	–	–	–
Region X									
Idaho	0	–	–	–	–	–	–	–	–
Oregon	0	–	–	–	–	–	–	–	–
Washington	0	–	–	–	–	–	–	–	–
Alaska	0	–	–	–	–	–	–	–	–
Hawaii	0	–	–	–	–	–	–	–	–
Virgin Islands	0	–	–	–	–	–	–	–	–
Puerto Rico	0	–	–	–	–	–	–	–	–

(1) WD = wire drawing
(2) S = spinning
(3) PS = paint stripping
(4) B = wet or dry grit blasting
(5) HT = heat treating
(6) P = painting
(7) H = honing
(8) D = descaling
(9) ST = stamping
(10) F = cold forming
(11) E = enameling
(12) M = machining.

PRODUCT MIX IN 70 SIC 3471 PLANTS (JOB SHOPS)(52)

					Metals Deposited													
Deburring	Passivating	Stripping	Grinding Polishing or Buffing	Other Plant Operations	Cu	Brass	Ni	Cr	Zn	Sn	Pb	Sn-Pb	Au	Ag	Pt-metals	Cd	Co	Fe
12	26	1	13	12	40	10	47	42	32	20	4	4	10	16	2	37	2	1
4	9	0	2	1	10	2	11	9	7	8	2	3	5	8	1	10	1	0
1	3	0	1	None	1	0	2	3	2	1	0	0	1	1	0	2	1	0
1	3	0	0	WD(1)	6	2	6	4	2	5	2	2	3	5	1	5	0	0
0	1	0	0	None	1	0	1	0	1	1	0	0	1	1	0	1	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	2	0	1	None	2	0	2	2	2	1	0	1	0	1	0	2	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	4	0	3	1	7	4	6	5	2	3	0	0	2	3	0	2	0	0
0	0	0	0	None	1	2	0	1	0	1	0	0	0	0	0	0	0	0
2	4	0	3	S(2), PS(3)	6	2	6	4	2	2	0	0	2	3	0	2	0	0
0	1	0	1	None	3	0	2	3	2	1	0	0	0	0	0	3	0	0
–	–	–	0	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0	0	0	1	None	1	0	1	1	1	0	0	0	0	0	0	1	0	0
0	1	0	0	None	2	0	1	2	1	1	0	0	0	0	0	2	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	2	0	1	None	2	1	2	2	2	2	0	0	0	0	0	2	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	1	0	0	None	1	1	1	0	1	1	0	0	0	0	0	1	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0	0	0	1	None	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1	1	0	0	None	1	0	1	1	1	1	0	0	0	0	0	1	0	0
2	3	0	3	5	11	1	16	13	13	3	1	0	1	1	0	12	1	0
0	0	0	1	B,HT(5)	2	0	4	2	3	0	1	0	0	0	0	2	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0	1	0	1	P(6)	1	0	3	3	3	1	0	0	0	0	0	3	1	0
0	0	0	0	HT(5)	2	0	2	1	1	1	0	0	1	1	0	1	0	0
1	2	0	1	H(7), B(4)	4	0	5	5	4	0	0	0	0	0	0	4	0	0
1	0	0	0	D(8)	2	1	1	2	2	1	0	0	0	0	0	2	0	0
0	0	0	0	1	0	0	1	2	1	0	0	0	0	0	0	1	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0	0	0	0	ST(9), F(10)	0	0	1	2	1	0	0	0	0	0	0	1	0	0
0	1	0	1	None	1	0	1	1	1	1	0	0	1	1	0	1	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0	1	0	1	None	1	0	1	1	1	1	0	0	1	1	0	1	0	0
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	6	1	2	4	6	2	8	8	4	2	1	1	1	3	1	6	0	1
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	6	1	2	E(11),B,P,M(12)H	6	2	8	8	4	2	1	1	1	3	1	6	0	1
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	None	–	–	–	–	–	–	–	–	–	–	–	–	–	–

cated Metal Products), 35 and 36 (Machinery), 37 (Transportation Equipment), 38 (Instruments and Related Products), 39 (Miscellaneous Manufacturing), and 19 (Ordnance and Accessories). The annual production of the metal finishing industry is measured as value added to the products of others. The distribution of these values can be related to the distribution of plants (Tables 2 and 3). A precise measure of the distribution of the materials and products processed is not feasible from the statistical data available. Similarly, no data are known to exist which would allow one to project the types of materials added to the products for any geographic region. The data of Table 1, discussed above, shows some trends of material usages.

CURRENT ECONOMIC STATUS

The number of manufacturing plants and employment in SIC 3471(53) for the years 1958 through 1972 are shown in Figure 1. The total number of plants is higher than the numbers given in Tables 2 and 3 for reasons given in the "Geographic Distribution of Plants" section of this report. The economic trends of the industry are not affected by the absolute number of facilities. Industry plants in general are small. More than 75 percent of the plants show fewer than 20 employees. The employment peaked in 1969 with 69,000 and decreased to near 52,000 employees by 1971. The latest census of manufacturing facilities, in 1972, shows a modest increase to about 53,000 employees.

The total number of plants also peaked in 1969 to about 3300 at a rate of approximately 65 plants, or 2.5 percent annually, for the period from 1958 to 1969. The following years to 1972 showed a stabilization of the number of industrial plants with an annual decrease of less than 10 plants or about 0.2 percent. The slightly fewer number of plants showed an increase in employment for the year 1972.

For 1972, the value added by manufacture was $749,100,000. The cost of materials and fuels was $297,400,000, or about 40 percent of the value added and 28 percent of the value of industry shipments of $1,062,100,000. The capital expenditures in 1972 were $41,000,000, up $9,920,000 or 32 percent from 1971, and amounted to about 4 percent of the value of industry shipments. Wages in 1972 were $393,300,000, an increase of 8 percent from $864,000,000 for the wages of the previous year, and represented 52 percent of the value added or nearly 38 percent of the value of industry shipments.

FUTURE TRENDS AND DEVELOPMENTS

Based on the statistical data from the Census of Manufactures for the years 1958 to 1972 (Figure 1) for the electroplating and metal finishing industry little or no growth is projected for the near future. Similarly, the number of employees is expected to hold near its present level. The value added by manufacture will increase as the costs for materials and labor increase. Price rises in fuel will contribute to

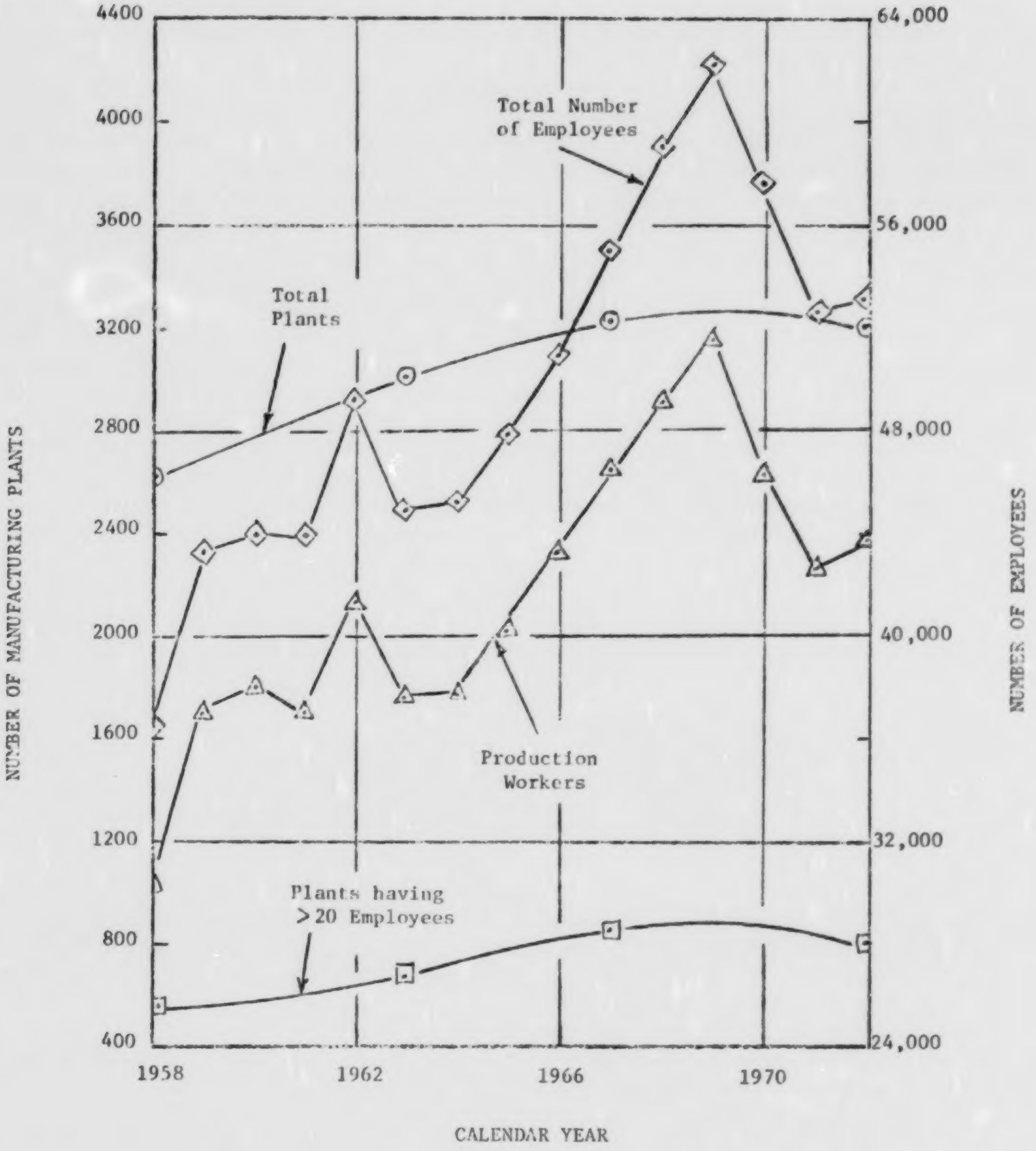

FIGURE 1. MANUFACTURING PLANTS AND EMPLOYMENT IN SIC 3471(53)

increased costs of shipments. The rate of these increases should follow the overall economic conditions prevalent for all manufacturing. Capital expenditures are expected to increase as replacement costs, purchase of new equipment, and plant space costs increase. Pollution control equipment will be needed to comply with Effluent Guideline regulations for the industry. The amount of these expenditures is undetermined since they are dependent on the severity of effluent restrictions. Consequently, expenditures for equipment purchases may range from $22,000 for a plant with less than 5 employees practicing only acid-base neutralization, to $400,000 for a plant with about 50 employees carrying out a complete wastewater treatment with clarification and filtering. The annual operating costs for such wastewater systems may range from $12,000 to $160,000, respectively. Some savings may be made possible by regeneration of plating chemicals.

Technical developments for the industry are expected in the area of metals reclamation from spent plating solutions and from rinses. Major breakthroughs can reduce the quantities of plating metals needed in production. Research efforts in the area of metal substitution by less costly materials may produce a reduction in process costs. An example would be the replacement of nickel with iron-nickel alloys for some products. Additionally, improved processes can be expected to provide material savings. New processes and new coating materials developed constantly find applications for products not previously finished by the electroplating industry, thus enhancing the economic growth potential.

GEOGRAPHIC DISTRIBUTION OF PLANTS

The geographic distribution of electroplating and metal finishing job shops was determined using the state directories of manufacturers(1-50). State directories were used in preference to federal statistics since the companies are identified by name and address, the distribution with regard to city size may be determined, and the data are more recent (that is, since 1972).

State directories contain listings of establishments (i.e., engraving, sand blasting of monuments, heat treating, and others of lesser importance) which are not truly metal finishing operations as defined for this study which was limited to

(1) Electroplating
(2) Anodizing and dyeing
(3) Electroless and immersion plating
(4) Chemical conversion coating (phosphate, chromate, etc.)
(5) Chemical polishing and electropolishing.

Specifically excluded from the study were

(1) Coloring
(2) Chemical milling and etching
(3) Electrochemical machining
(4) Pickling, descaling, bright dipping, stripping
(5) Electropainting.

In dealing directly with the state directories, it was possible to exclude plants other than those in the first category. This is reflected in a lesser number of facilities. Additionally, the use of the data from state directories enabled a breakdown as to the size of towns in which electroplating and metal finishing establishments are located.

The number of job shops is listed in Table 2 by State, EPA Region, and nationally, under the headings of size of towns or cities.

As shown in Table 2, the heaviest concentration of electroplating and metal finishing facilities are in the North Central Region of the U.S. EPA Region V has nearly 40 percent of the total number of industry job shops, with Michigan accounting for 12 percent followed by Ohio (over 11 percent) and Illinois (~8 percent). The Atlantic Coast states are second with 35 percent of the electroplating and metal finishing plants. The third heaviest concentration is in EPA Region IX, particularly in the State of California (6 percent). The remaining sectors of the country share 20 percent of the electroplating and metal finishing plants. This distribution appears to be coincident with that for manufacturing facilities. For example, the heavy concentration of electroplating and metal finishing plants in Michigan, Ohio, and Illinois coincides with the automotive industry in that area.

Evaluation of the data presented in Table 2 also shows that more than 52 percent of all electroplating and metal finishing establishments are located in cities having a population greater than 100,000, and that more than three quarters of the plants are located in towns with a population greater than 20,000. Only 10 percent of the establishments are in towns with a population of less than 5,000 inhabitants. The fact that 52 percent or more than 75 percent of the job shops are located in cities of more than 100,000 or 20,000 population, respectively, is reasoned to affect the type of treatment and disposal practices employed by the plants so located. It is reasoned that the urban location of the electroplating and metal finishing industry would result in limits (either physical or economic) on plant space available for the treatment and disposal of wastes, and would also be associated with wastewater disposal to sewers according to applicable local regulations. Thus, the distribution in large cities cited above would be reasoned to favor such waste disposal practices as sewering of liquid wastes (with or without treatment or solids separation) and off-site disposal of nonsewerable wastes, thus the use of contractor services. The prevalence of such practices is discussed in a later section of this report.

DISTRIBUTION OF PLANTS BY SIZE

The distribution of establishments by number of employees is shown in Table 3. Examination of this table reveals that 89 percent of the total number of plants have 1 to 50 employees. The greatest percentage (30 percent) have 11 to 25 employees, with 27 percent having 5 to 10, 20 percent having 26 to 50, and 12 percent 1 to 4 employees. About half of the plants employing more than 100 persons and over 40 percent employing more than 50 persons are located in Region V.

TABLE 2. DISTRIBUTION OF PLANTS BY THE NUMBER OF ESTABLISHMENTS(1-51)

EPA Region and State	Number of Plants(a) A	B	C	D	Total	Percent Distribution of Plants(a) A	B	C	D	Total
Region I	16	55	135	120	326	0.71	2.44	5.99	5.32	14.46
Massachusetts	7	16	59	34	116	0.31	0.71	2.63	1.51	5.16
Connecticut	7	29	51	37	124	0.31	1.29	2.27	1.64	5.51
Rhode Island	0	5	23	49	77	----	0.22	1.02	2.18	3.42
New Hampshire	1	2	0	0	3	0.04	0.09	----	----	0.13
Maine	1	0	2	0	3	0.04	----	0.09	----	0.13
Vermont	0	3	0	0	3	----	0.13	----	----	0.13
Region II	44	37	64	132	277	1.95	1.64	2.84	5.86	12.29
New Jersey	16	22	36	39	113	0.71	0.97	1.60	1.73	5.01
New York	28	15	28	93	164	1.24	0.67	1.24	4.13	7.28
Region III	33	34	37	72	176	1.46	1.51	1.64	3.20	7.81
Delaware	0	0	0	1	1	----	----	----	0.04	0.04
Maryland	1	2	3	14	20	0.04	0.09	0.13	0.62	0.88
Pennsylvania	28	30	25	55	138	1.25	1.33	1.11	2.45	6.14
Virginia	1	0	0	2	3	0.04	----	----	0.09	0.13
West Virginia	3	2	9	0	14	0.13	0.09	0.40	----	0.62
Region IV	29	20	41	67	157	1.29	0.89	1.82	2.97	6.97
Alabama	5	2	8	6	21	0.22	0.09	0.36	0.27	0.94
Florida	7	4	13	17	41	0.31	0.18	0.58	0.76	1.83
Georgia	3	1	3	9	16	0.13	0.04	0.13	0.40	0.70
Kentucky	2	3	1	6	12	0.09	0.13	0.04	0.27	0.53
Mississippi	2	2	2	2	8	0.09	0.09	0.09	0.09	0.36
North Carolina	5	3	5	10	23	0.22	0.13	0.22	0.44	1.01
South Carolina	4	2	4	2	12	0.18	0.09	0.18	0.09	0.54
Tennessee	1	3	5	15	24	0.04	0.13	0.22	0.67	1.06
Region V	89	104	174	494	861	3.95	4.61	7.72	21.92	38.20
Illinois	8	14	44	123	189	0.36	0.62	1.95	5.46	8.39
Indiana	8	13	22	26	69	0.36	0.58	0.98	1.14	3.06
Michigan	49	35	55	137	276	2.18	1.54	2.41	6.09	12.24
Minnesota	3	4	6	18	31	0.13	0.18	0.27	0.80	1.38
Ohio	16	34	33	179	262	0.70	1.51	1.47	7.94	11.62
Wisconsin	5	4	14	11	34	0.22	0.18	0.62	0.49	1.51
Region VI	2	7	13	77	99	0.09	0.31	0.58	3.41	4.39
Arkansas	0	1	2	2	5	----	0.04	0.09	0.09	0.22
Louisiana	0	0	1	1	2	----	----	0.04	0.04	0.09
New Mexico	0	0	0	6	6	----	----	----	0.27	0.27
Oklahoma	0	1	0	17	18	----	0.04	----	0.76	0.80
Texas	2	5	10	51	68	0.29	0.22	0.44	2.26	3.01
Region VII	14	15	15	71	115	0.62	0.67	0.67	3.14	5.10
Iowa	7	2	9	4	22	0.31	0.09	0.40	0.18	0.98
Kansas	1	7	0	13	21	0.04	0.31	----	0.58	0.93
Missouri	6	5	6	50	67	0.27	0.22	0.27	2.21	2.97
Nebraska	0	1	0	4	5	----	0.04	----	0.18	0.22
Region VIII	2	2	4	23	31	0.09	0.09	0.18	1.02	1.38
Colorado	1	1	2	18	22	0.04	0.04	0.09	0.80	0.98
Montana	1	0	0	0	1	0.04	----	----	----	0.04
North Dakota	0	0	0	0	0	----	----	----	----	----
South Dakota	0	0	1	0	1	----	----	0.04	----	0.04
Utah	0	1	1	5	7	----	0.04	0.04	0.22	0.31
Wyoming	0	0	0	0	0	----	----	----	----	----
Region IX	3	14	52	94	163	0.13	0.62	2.31	4.17	7.23
Arizona	1	1	1	15	18	0.04	0.04	0.04	0.67	0.80
California	1	13	48	74	136	0.04	0.58	2.13	3.29	6.03
Hawaii	0	0	0	3	3	----	----	----	0.13	0.13
Nevada	1	0	3	2	6	0.04	----	0.13	0.09	0.27
Region X	0	1	13	35	49	----	0.04	0.58	1.55	2.17
Alaska	0	0	0	0	0	----	----	----	----	----
Idaho	0	0	3	0	3	----	----	0.13	----	0.13
Oregon	0	0	4	18	22	----	----	0.18	0.80	0.98
Washington	0	1	6	17	24	----	0.04	0.27	0.75	1.06
Total United States	232	289	548	1,185	2,254	10.29	12.82	24.33	52.56	100.00

(a) Classified by City Population: A = <5000; B = 5000 to 20,000; C = 20,000 to 100,000; D = >100,000.

TABLE 3. DISTRIBUTION OF ELECTROPLATING AND METAL FINISHING JOB-SHOPS BY SIZE (NUMBER OF EMPLOYEES)

EPA Region and State	Number of Employees										Total
	1-4	5-10	11-25	26-50	51-75	76-100	101-150	151-250	251-500	Not Given	
Region I	53	66	55	116	7	10	1	6	–	12	326
Massachusetts	23	25	31	29	–	6	–	–	–	2	116
Connecticut	30	36	22	15	6	3	1	1	–	10	124
Rhode Island	–	–	–	71	–	1	–	5	–	–	77
New Hampshire	–	1	2	–	–	–	–	–	–	–	3
Maine	–	2	–	–	1	–	–	–	–	–	3
Vermont	–	2	–	1	–	–	–	–	–	–	3
Region II	1	73	110	53	13	8	5	1	–	13	277
New Jersey	1	41	44	18	3	1	2	–	–	3	113
New York	–	32	66	35	10	7	3	1	–	10	164
Region III	42	38	51	25	5	7	2	–	–	6	176
Delaware	–	–	1	–	–	–	–	–	–	–	1
Maryland	7	4	7	2	–	–	–	–	–	–	20
Pennsylvania	35	30	39	17	4	5	2	–	–	6	138
Virginia	–	–	–	2	1	–	–	–	–	–	3
West Virginia	–	4	4	4	–	2	–	–	–	–	14
Region IV	22	42	42	34	6	5	1	1	1	3	157
Alabama	–	9	5	5	–	1	–	–	–	1	21
Florida	9	13	13	3	1	–	–	–	–	2	41
Georgia	5	3	3	2	2	–	1	–	–	–	16
Kentucky	1	3	1	5	1	1	–	–	–	–	12
Mississippi	–	1	6	–	–	1	–	–	–	–	8
North Carolina	2	4	7	8	–	1	–	1	–	–	23
South Carolina	1	4	4	1	2	–	–	–	–	–	12
Tennessee	4	5	3	10	–	1	–	–	1	–	24
Region V	88	215	247	120	42	24	16	12	4	93	861
Illinois	19	53	57	32	10	5	6	2	1	4	189
Indiana	–	21	26	10	–	6	–	3	–	3	69
Michigan	19	54	69	32	16	8	4	3	2	69	276
Minnesota	–	6	12	4	3	–	–	1	–	5	31
Ohio	50	73	71	38	11	3	5	3	–	8	262
Wisconsin	–	8	12	4	2	2	1	–	1	4	34
Region VI	8	30	31	18	2	9	–	–	–	1	99
Arkansas	–	2	–	2	–	1	–	–	–	–	5
Louisiana	–	1	–	1	–	–	–	–	–	–	2
New Mexico	–	5	–	1	–	–	–	–	–	–	6
Oklahoma	8	4	3	1	2	–	–	–	–	–	18
Texas	–	18	28	13	–	8	–	–	–	1	68
Region VII	22	28	34	11	3	10	6	–	1	–	115
Iowa	–	15	–	3	–	2	2	–	–	–	22
Kansas	–	–	14	–	–	4	3	–	–	–	21
Missouri	22	13	17	6	3	4	1	–	1	–	67
Nebraska	–	–	3	2	–	–	–	–	–	–	5
Region VIII	–	16	6	4	3	2	–	–	–	–	31
Colorado	–	12	2	3	3	2	–	–	–	–	22
Montana	–	1	–	–	–	–	–	–	–	–	1
North Dakota	–	–	–	–	–	–	–	–	–	–	–
South Dakota	–	1	–	–	–	–	–	–	–	–	1
Utah	–	2	4	1	–	–	–	–	–	–	7
Wyoming	–	–	–	–	–	–	–	–	–	–	–
Region IX	13	41	55	33	6	4	2	3	1	5	163
Arizona	2	5	6	4	–	1	–	–	–	–	18
California	7	31	49	29	6	3	2	3	1	5	136
Hawaii	2	1	–	–	–	–	–	–	–	–	3
Nevada	2	4	–	–	–	–	–	–	–	–	6
Region X	8	18	15	4	2	1	–	–	–	1	49
Alaska	–	–	–	–	–	–	–	–	–	–	–
Idaho	–	1	2	–	–	–	–	–	–	–	3
Oregon	8	5	5	–	2	1	–	–	–	1	22
Washington	–	12	8	4	–	–	–	–	–	–	24
Total Regions I-X	257	567	646	418	89	80	33	23	7	134	2254

Other measures of size that could be used in this industry include surface area processed, power consumption, or consumption of chemicals. The variety of work done in job shops, the variation in the number of steps used by different shops to produce the same nominal finish, the degree of automation of the process, and the variations in practice make the description of size of operation by such measures so complex as to preclude the presentation of any overall data for the industry.

DISTRIBUTION OF PLANTS BY AGE

The types of electroplating and metal finishing operations conducted are the same in all facilities regardless of the age for a given process. The quantity of waste produced is also independent of the age of the facility. Older installations employ mainly hand-operated equipment, while in newer facilities equipment tends to be automated. However, for a given product being finished, the loss of chemical solutions per unit area processed is the same for both manual and automated operations and consequently the same quantity of water pollution control sludges is generated. In terms of polishing or buffing, automatic operations are somewhat more efficient than manual operations because of equalized wheel pressure and the uniform applications of the compound. Automated equipment installed within the past 20 years is expected to produce 10 to 20 percent less waste than older manual equipment.

A sampling of the industry established no definite age range among the facilities. Companies report having equipment as new as 2 years and as old as 30 years. Equipment is continuously purchased as the changes in product mix and/or the volume of business dictate. The work being done by the industry on materials owned by others requires flexibility in processes as well as in size of equipment. Waste treatment equipment for chemical in-line or end-of-line waste control is generally less than 5 years old, although some equipment has been used for about 25 years.

DISTRIBUTION OF PLANTS BY PROCESS

Statistical data on the distribution of the processes used in the industry is nonexistent. The analysis that follows is based on the information supplied by 70 facilities during this study. The results are given in Table 1. Electroplating operations are reported in 65 of the plants which together deposit 14 different metals or alloys in 265 rack- or barrel-type operations. Copper, nickel, chromium, zinc, and cadmium comprise nearly 80 percent of the operations. Less than one third of the plants have tin-plating operations, about 20 percent plate silver, and about 15 percent have installations for plating brass and gold. Lead and lead alloys, iron, cobalt, and the platinum metals are deposited in the lowest number of facilities.

A chromating operation is in existence in 50 of the 70 facilities. Most applications of the process are on zinc deposits. Electroless plating of nickel and copper is carried out in 30 percent of the plants, and processes for phosphating of steel and anodizing of aluminum are practiced in just under 30 percent of the reporting facilities. Of the 19 plants that reported anodizing, 17 are applying dyes to finish coatings. About one third of the plants have equipment for passivating metals to protect against tarnish and corrosion. These applications would be most common on copper and copper alloys and silver.

Some form of basis metal preparation is carried out in almost half of the facilities. Bright dipping and chemical polishing produce acid metal wastes and are carried out in at least 45 percent of the plants. Deburring, grinding, polishing, or buffing is reported by 12 or 13 plants, about 17 percent of the facilities. Twelve of the plants reported the performance of other operations, normally not associated with metal finishing, such as machining, enameling, stamping, painting, or heat treating.

The national distribution of the reporting facilities follows approximately the distribution of plants as given in Table 2 (state directories distribution). Thirty percent of the plants are located in EPA Region V, heavily engaged in copper, nickel, chromium, zinc, and cadmium plating with very little activity in precious metals plating (< 7%). About one half of all precious metals operations were reported from Region I which has 20 percent of the total facilities. Region IX, specifically California, with about 18 percent of the facilities reporting, appears to have the most uniform metal finishing process distribution. All tabulated processing with the exception of cobalt plating is performed in Region IX. Consequently, job shop electroplating process characteristics can be expected to coincide with the industrial activities in a given area. The automotive manufacturing industry in the Midwest, requiring copper, nickel, chromium, and zinc coatings for corrosion protection causes a concentration of such facilities in that area. Similarly, the production of electronic gear, printed circuits, and precious metal products carried out in the Northeast and California required that specific electroplating processes needed for products by those industries are concentrated in these regions. Such a distribution will have a bearing on characteristic wastes and their quantities for each region or state.

REFERENCES
INDUSTRY CHARACTERIZATION

(1) Director of Alaska Commercial Establishments, July, 1974, State of Alaska, Department of Economic Development, Division of Economic Enterprise, Pouch E, Juneau.

(2) Arizona Directory of Manufactures, 1974, Arizona Department of Economic Security, Phoenix, Arizona.

(3) Director of Manufacturers in Arkansas, 1974 Edition, Arkansas Industrial Development Foundation, Little Rock, Arkansas.

(4) 1974 California Manufacturers Register, California Manufacturers Association, Los Angeles, California, 1974.

(5) 1974 Connecticut State Industrial Directory, Connecticut State Industrial Director, New York, New York, 1974.

(6) Directory of Commerce and Industry, State of Delaware, 1970, Delaware State Chamber of Commerce, Inc., Delaware, 1970.

(7) Director of Florida Industries, 1973 Florida State Chamber of Commerce, Jacksonville, Florida, 1973.

(8) Directory of Manufacturers, State of Hawaii, Chamber of Commerce of Hawaii, Honolulu, Hawaii, 1973.

(9) Manufacturing Directory of Idaho, 1973 Idaho Department of Commerce and Development, Boise, Idaho, 1973.

(10) Chicago Buyer's Guide, Chicago Association of Commerce and Industry, Chicago, Illinois, 1975.

(11) The Indiana Industrial Directory (1972-73 Edition), The Indiana State Chamber of Commerce, Indianapolis, Indiana, 1972.

(12) Directory of Iowa Manufacturers 1973-1974, The State of Iowa - Iowa Development Commission, Des Moines, Iowa.

(13) 1974 Kentucky Directory of Manufacturers, Seventeenth Edition, Kentucky Department of Commerce, Frankfort, Kentucky.

(14) Louisiana Directory of Manufacturers, 1972 Edition, State of Louisiana, Department of Commerce and Industry, Baton Rouge, Louisiana.

(15) Directory 1973-1974 Maryland Manufacturers, Maryland Division of Economic Development, Anapolis, Maryland, 1973.

(16) Massachusetts Industrial Directory 1971, Massachusetts Department of Commerce and Development, Boston, Massachusetts.

(17) The Directory of Michigan Manufactures, 1971, Manufacturer Publishing Company, Detroit, Michigan, 1970.

(18) Maine Buyer's Guide and Directory of Maine Manufacturers, 1970, 1971, Maine Department of Economic Development, Augusta, Maine, 1970.

(19) Minnesota Directory of Manufacturers 1975-76, Minnesota Department of Economic Development, St. Paul, Minnesota.

(20) 1971-1972 Mississippi Manufacturers Directory, Mississippi Research and Development Center, Jackson, Mississippi, 1972.

(21) Missouri Directory of Manufacturing and Mining, 1973 Edition, Missouri Division of Commerce and Industrial Development, Jefferson City, Missouri.

(22) Montana Directory of Manufacturers, 1973-1974, Department of Intergovernmental Relations, Helena, Montana.

(23) Nebraska Manufacturers and Their Products, 1974-1975, Nebraska Department of Economic Development, Lincoln, Nebraska.

(24) 1974 Directory of Nevada Businesses, Department of Economic Development, Carson City, Nevada.

(25) Made in New Hampshire, 1975, State of New Hampshire, Office of Industrial Development, Division of Economic Development, Department of Resources and Economic Development, Concord, New Hampshire.

(26) 1975 New Jersey State Industrial Directory, New Jersey State Industrial Directory, New York, New York, 1975.

(27) 1974-1975 Directory of New Mexico Manufacturing and Mining, Economic Development Division of the New Mexico Department of Development and Bureau of Business and Economic Research, Institute for Social Research and Development, The University of New Mexico, Santa Fe, New Mexico, May, 1974.

(28) 1974 New York State Industrial Directory, New York State Industrial Directory, New York, New York, 1974.

(29) Directory of North Carolina Manufacturing Firms, 1974-75 Edition, Division of Commerce and Industry, Office of Industrial Tourist and Community Resources, Department of Natural and Economic Resources, Raleigh, North Carolina.

(30) 1972-1973 Directory of North Dakota Manufacturers, Business and Industrial Development Department, Bismarck, North Dakota.

(31) 1975 Directory of Ohio Manufacturers, Ohio Department of Economic and Community Development, Columbus, Ohio.

(32) Supplement to the Geographical Section, Oklahoma Directory of Manufacturers and Products, 1974 Edition, March, 1975.

(33) 1975 Georgia Manufacturing Directory, Georgia Bureau of Industry and Trade, Atlanta, Georgia.

(34) Directory of Oregon Manufacturers, 1974, Oregon Economic Development Commission, State of Oregon, Department of Economic Development, Portland, Oregon.

(35) 1973 Industrial Directory of the Commonwealth of Pennsylvania, Twenty First Edition, Department of Commerce, Harrisburg, Pennsylvania, 1973.

(36) Rhode Island Directory of Manufacturers and List of Commercial Establishments, The Rhode Island Development Council, Providence, Rhode Island, January, 1973.

(37) Oklahoma Directory of Manufacturers and Products, 1974 Edition, State of Oklahoma, Oklahoma Industrial Development Department, Oklahome City, Oklahoma.

(38) Industrial Directory of South Carolina, Planning and Research Division, South Carolina State Development Board, Columbia, South Carolina, 1973-1974.

(39) 1972 Directory of South Dakota Manufacturers and Processors, South Dakota Industrial Development Expansion Agency, Pierre, South Dakota.

(40) Directory of Texas Manufacturers, 1974, Bureau of Business Research, The University of Texas at Austin, Austin, Texas, 1974.

(41) Directory of Utah Manufacturers, 1975-76, Utah Department of Employment Security, Salt Lake City, Utah.

(42) Directory of Washington Manufacturers, 1974, Trade Development Commission, Washington State Department of Commerce, Olympia, Washington.

(43) Wast Virginia Manufacturing Directory, 1974, West Virginia Department of Commerce, Industrial Development Division, Charleston, West Virginia.

(44) Classified Directory of Wisconsin Manufacturers 1974, Wisconsin Manufacturers Association, Milwaukee, Wisconsin, 1973.

(45) Wyoming Directory of Manufacturing and Mining, 1973, Wyoming Department of Economic Planning and Development, Cheyenne, Wyoming.

(46) Directory of Colorado Manufacturers, 1974-75, Business Research Division, University of Colorado, Boulder, Colorado, 1974.

(47) 1974-1975 Vermont Directory of Manufacturers, Agency of Development and Community Affairs, Montpelier, Vermont.

(48) Dun & Bradstreet Metalworking Directory 1974, Dun & Bradstreet, New York, New York, 1974.

(49) Directory of Kansas Manufacturers and Products, Kansas Industrial Development Commission, Topeka, Kansas.

(50) Directory of Tennessee Industries, Tennessee State Planning Commission, Nashville, Tennessee.

(51) Industrial Alabama, A Directory of Manufacturers 1972-1973, Alabama State Chamber of Commerce, Mongomery, Alabama.

(52) Written information supplied by personnel at job shops to the contractor through the National Association of Metal Finishers.

(53) U. S. Bureau of the Census, Census of Manufactures, 1972, Industry Series: Screw Machine Products, Fasteners and Washers; Metal Forgings and Stampings; and Metal Services, MC72(2)-34D, U. S. Government Printing Office, Washington, D.C., 1975.

II. WASTE CHARACTERIZATION

INTRODUCTION

This section provides generalized process description, criteria for defining a waste as potentially hazardous are presented, and various plating operations are discussed in detail. Also presented are survey data and descriptions of the model plants together with a discussion on the types and quantities of wastes generated.

GENERALIZED PROCESS DESCRIPTION

The electroplating and metal finishing industry is characterized by many individual variations of both practice and terminology. The discussion presented in this subsection is general in nature. A more detailed discussion is presented in a later subsection (see p. 24) and in Appendixes B, C, and D. A glossary is presented in Appendix I.

The service offered by this industry may vary from a single operation to multiple-step processing. The operations may be classified in many ways in various degrees of discrimination. For the first part of this discussion, the operations are classified into three different categories: mechanical, chemical, and electrochemical.

Mechanical operations include grinding, grit blasting, shot blasting, buffing, deburring, and polishing.

Chemical processes in the industry include degreasing, acid pickling, alkaline cleaning, acid cleaning, surface neutralizing, chromating, phosphating, bright dipping, chemical polishing, passivating, and stripping. Special cases in this category are electroless nickel and electroless copper plating, in which the surface of the workpiece acts as a catalyst for the decomposition of the solution, with the deposition of a metal on the workpiece.

Electrochemical processes in the industry include anodic cleaning, cathodic cleaning, anodizing, and electroplating. Special cases under this category would include those processes which use no external electrical connections but depend on the electrochemical reactions between the basis material and the solution to produce a metallic coating, such as stannating and zincating. These latter processes are referred to as immersion plating.

The above operations may be performed singly or in combination to produce the surface properties desired by a customer.

Electroplating and Metal Finishing Engineering

The purpose of this section is to summarize the principles and methods that are applied in the finishing of metallic or nonmetallic substrates or basis materials. The condition of these substrates, especially the metals, has a direct bearing on the properties and the performance of the electrodeposits. Consequently, basis metals are generally prepared for plating by mechanical, chemical or electrochemical finishing. Metal imperfections, scales, oils, and grease must be removed from the surface if electroplating is to be successful.

Oils, grease, buffing, polishing compounds, etc., may be removed by alkaline spray cleaners or by vapor degreasing and this is commonly carried out before scale removal. Scales and oxides can be removed by chemical pickling in strong acids, sometimes in combination with the mechanical finishing processes described in the next paragraph. In electropolishing operations the metal is made from the anode and its surface is improved by selective dissolution. This process has found wide application for steels, aluminum and other nonferrous single-phase metals and alloys.

In the mechanical finishing processes of polishing, buffing, and grinding, the surface of the work is cut or worked by abrasives which are moved over the surface of the work by rotating wheels or moving belts. Deburring may be performed manually or by placing many small workpieces in a rotating container, with abrasive materials, so that a smoothing action results. Shot blasting or grit blasting involves the entrainment of the shot or grit in a stream of air so as to impact the workpiece. The equipment required is that providing a forced air stream, an enclosure, grit collection, and air pollution control. Workpieces may be processed by hand or on racks, conveyors, or holders.

The plating cycle following the pretreatment steps can be very simple, such as a sequence of cleaning-rinsing-plating-rinsing-drying, or very complex, requiring a number of cleaning steps with additional steps of acid dipping, striking, activation, multiple rinses and the deposition of more than one metal. All processing steps within a given cycle must be arranged so that the solutions will not be contaminated. Cleaners, acid dips and strikes vary in composition and concentration and are formulated for a particular basis material. Cleaners are generally alkaline and are used to remove the last traces of oil and grease. Acid dips are not intended to remove scales or oxides but are used to neutralize traces of alkaline cleaners left on the basis material after rinsing and to activate the surface to receive the electrodeposit. Some materials require more intense activation steps than others. Dilute acids, mainly H_2SO_4 or HCl, are sufficient for the preparation of copper base alloys or carbon steels for plating, whereas stainless steels require a cathodic activation step in a $NiCl_2$-HCl solution. Each basis material must be treated differently and each metal deposited requires a specific cycle.

Metal deposition can occur from acid or alkaline solutions. The most important acid plating baths contain the metal salt in a form of a sulfate or chloride or a mixture of the two with some free acid present and some inorganic buffer to maintain a specific solution pH. Examples are plating solutions for nickel, copper, iron, zinc and the platinum metals. Lead, tin, or copper solutions may be prepared with fluoborates, and sulfamate is often used for nickel plating. Chromium deposition takes place in solutions made up with chromic acid which dissociates into an anion radical in water. Copper, zinc, cadmium, silver or gold are deposited from alkaline solutions, often containing cyanides. Besides the single metals, a large combination of alloys can be electrodeposited from all types of solutions cited above.

Each process cycle is composed of such process steps, and the time required for each cycle varies with the number of stations in each cycle, the transfer time from station to station, the type of basis material processed, and the coating or coatings which are deposited. Coating specifications determine what thicknesses of metals are to be deposited, varying from less than 1 to several tens of micrometers.

Thus, each electroplating operation is comprised of a number of steps of different duration, where the products are moved in a sequence from one chemical solution to another. Solution volume, and therefore rank size, depends on product size, shape, and the number of parts to be processed per unit time. Tank materials and equipment must be chemically inert to the solutions at their operating temperature. Heating or cooling must be provided for the solutions, and equipment must be installed for solution agitation, filtration, and piping for transfer as well as fume control. Direct current power is carried from motor generators or rectifiers to the electrochemically operated solutions by means of copper busbars. Parts may be processed in barrels or on racks.

Barrel operations are used for small parts that tumble freely in rotating barrels. Perforated plastic barrels range in diameter from 15 to 75 cm (6 to 30 in.), depending on part size and shape. Direct current is distributed to the parts being plated in horizontal barrels through danglers suspended from a current-carrying bar located at the longitudinal axis. In obliquely oriented barrels, a conductive button at the bottom transmits the current.

Rack plating is required for a large percentage of the surface area processed commercially. Racks are used for reasons including maintenance of shape or surface conditions, achievement of the desired distribution of coating, or size or shape of workpiece. The parts are attached to plastic-coated copper frames designed to carry the current equitably to a few hundred small parts, several medium-sized shapes, or just a few large products through spring-like rack tips affixed to the rack splines. Racks fabricated for manual transfer from cleaning, plating, and rinsing tanks usually contain 2 to 7 kg (5 to 15 pounds) of parts having a surface area of 0.5 to 1 sq meter (5 to 10 sq ft). Larger racks for holding heavier parts are constructed for use with mechanical hoist and transfer systems.

Process Sequencing

The sequence of unit operations is exemplified in Tables 4, 5, 6, and 7 for the plating of different substrate metals with chromium, nickel, or zinc, exclusive of substrate preparation. Oil and grease are removed by vapor degreasing. Scales and oxides are dissolved in acid pickles, by anodic action or mechanically. Aluminum and its alloys are finished by bright dipping. In the pretreatment steps parts may be soak cleaned, or anodically or cathodically treated in alkaline or acid solutions. Preplate operations are composed of so-called strikes, which describes short-time plating from low pH solutions (highly acidic) with low metal content at relatively high current densities. The plate may vary, as the required properties of each coating varies. Further discussions of the indicated processes are given in the section on "Detailed Process Descriptions".

CRITERIA FOR DEFINING A WASTE AS POTENTIALLY HAZARDOUS

The wastes generated by the electroplating and metal finishing industry contain heavy metals and organic solvents. Because the prevalent disposal practice for these wastes is to the land, the possibility exists that these metals and solvents may become a part of the leachate from landfill operations and drain into surface and underground water supplies. While many of these materials are potentially hazardous to terrestrial and aquatic life, the greatest concern is their potential hazard to human health.

Although there are many criteria for judging the potential hazardous nature of various materials, one set of criteria which has been accepted for many years is the acceptable level of various components in public water supplies. Because this set of criteria deals directly with the human health issue, it has been selected as the basis for the conclusion that all of the metal-bearing wastes from electroplating and metal finishing operations are potentially hazardous.

A table of surface water criteria for public water supplies is reproduced as Table 8. As shown there, the permissible levels for the heavy metals are all low, generally less than 1 mg/l. These data also indicate that it is highly desirable for these components to be completely absent from public water supplies.

There also have been a growing concern regarding the potential hazard to human health from various organic solvents, particularly the possible carcinogenicity of chlorinated hydrocarbons. This factor together with the flammable nature of some solvents, is the basis for designating those wastes which contain solvents as potentially hazardous.

The criteria set forth above effectively mean that all four categories of wastes generated in the subject industry are potentially hazardous because of the presence of heavy metals and/or organic solvents.

TABLE 4. PROCESSING SEQUENCES FOR CHROMIUM PLATING

Required Process	Steels			Cast Iron	Copper and Its Alloys	Zinc Die Castings	Aluminum and Its Alloys	Nickel and Its Alloys
	Low Carbon	High Carbon	Stainless					
1) Oil and grease removal	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease
2) Scale removal	Acid pickle, rinse	Anodic pickle, rinse	HNO_3/HF, rinse	Mechanical or anodic pickle rinse	Acid or cyanide dip, rinse	Mechanical, rinse	Bright dip, rinse	Pickle, rinse
3) Pretreatment	Anodic clean, rinse	Anodic clean, rinse	Soak clean, rinse	Anodic clean, rinse	Cathodic clean Anodic clean, rinse	--	Soak clean, rinse	--
	Anodic chromic acid	Anodic chromic acid	Anodic clean, rinse	Anodic in chromic acid	Acid dip, rinse		Cathodic etch, rinse	
	--	--	Acid dip, rinse or anodic in chromic acid				Acid dip, rinse or sequence "A"	
4) Preplate	--	--		Chrome flash	--		Copper	Copper or nickel
5) Plate	Hard chromium, rinse	Hard chromium, rinse	Decorative or hard chromium, rinse	Hard chromium, rinse	Decorative chromium, rinse	Decorative chromium, rinse	Decorative chromium, rinse	Decorative chromium, rinse
	Hot rinse	Hot rinse	Hot rinse	Hot rinse	Hot rinse	Hot rinse	Hot rinse	Hot rinse

TABLE 5. PROCESSING SEQUENCES FOR NICKEL PLATING

Required Process	Steels			Cast Iron	Copper and Its Alloys	Zinc Die Castings	Aluminum and Its Alloys	Nickel and Its Alloys
	Low Carbon	High Carbon	Stainless					
1) Oil and grease removal	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease
2) Scale removal	Acid pickle, rinse	Anodic pickle, rinse	HNO_3/HF, rinse	Mechanical or anodic pickle, rinse	Acid or cyanide, rinse	Mechanical	Bright dip, rinse	Pickle, rinse
4) Preplate	Nickel strike	Nickel strike	Activate (anodic or cathodic)	Nickel strike	--	Cu-strike Cyanide copper, rinse Acid dip, rinse Acid Copper, rinse	Cu-strike, rinse Acid dip, rinse	Nickel strike
5) Nickel plate	**Watts nickel Semibright nickel Bright nickel Any one or any combination thereof } for all basis metals in this table.**							

TABLE 6. PROCESSING SEQUENCES FOR ZINC PLATING

Required Process	Steels		Cast Iron	Copper and Its Alloys	Aluminum and Its Alloys
	Low Carbon	High Carbon			
(1) Oil and grease removal	Degrease	Degrease	Degrease	Degrease	Degrease
(2) Scale removal	Acid pickle, rinse	Anodic pickle, rinse	Mechanical, or anodic pickle, rinse	Acid or cyanide dip, rinse	Bright dip, rinse
(3) Pretreatment	Soak clean, rinse Anodic clean, rinse Cyanide dip, rinse	Soak clean Cathodic clean, rinse Acid dip or anodic acid, rinse	Soak clean Cathodic clean, rinse Acid dip or anodic acid, rinse		
(4) Preplate	--	Copper strike or acid zinc strike, rinse	Copper strike or acid zinc strike, rinse	Copper strike, rinse*	
(5) Plate	High cyanide zinc or low cyanide zinc or acid zinc or zinc fluoborate rinse	for all basis metals in this table			
(6) Posttreatment	Acid bright dips Acid rinse Chromate conversion coatings rinse Hot rinse	for all basis metals in this table			

* For soldered parts only.

TABLE 7. PROCESSING SEQUENCES--DECORATIVE COPPER-NICKEL-CHROMIUM PLATING

Required Process	Steels			Cast Iron	Copper and Copper Base Alloys	Zinc Die Coatings	Aluminum and Its Alloys	Nickel and Its Alloys
	Low Carbon	High Carbon*	Stainless					
(1) Oil and grease removal	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease	Degrease
(2) Scale removal	Acid pickle, rinse	Anodic pickle, rinse	HNO_3/HF rinse	Mechanical or anodic pickle, rinse	Acid or cyanide dip, rinse	Mechanical, rinse	Bright dip, rinse	Pickle, rinse
(3) Pretreatment	Soak clean, rinse	Soak clean, rinse	Electropolish, rinse	Soak clean, rinse	Cathodic or anodic rinse	Cathodic or anodic rinse	Soak clean, rinse	Cathodic clean, anodic clean, rinse
	Anodic clean, rinse	Anodic clean, rinse	Anodic clean, rinse	Cathodic clean, rinse	Acid or cyanide dip, rinse	Acid dip, rinse	Acid dip, rinse	Cyanide dip, rinse
	Acid dip, rinse	Etch, rinse		Anodic acid rinse				Acid dip, rinse
		Anodic clean or NaCN-dip, rinse Acid dip, rinse						
(4) Preplate	Copper strike, rinse	Copper strike, rinse	Activate (anodic or cathodic)	--	--	Copper strike	Zinc immersion, rinse Zinc immersion, rinse Copper strike	Activate (anodic or cathodic)
(5) Copper plate	Cyanide copper, rinse or acid dip, rinse Acid copper, rinse	Cyanide copper, rinse, or acid dip, rinse Acid copper, rinse	--	Cyanide copper, rinse or acid dip, rinse Acid copper, rinse	Cyanide copper, rinse	Cyanide copper, rinse Acid dip, rinse Acid copper, rinse	Cyanide copper, rinse Acid dip, rinse Acid copper, rinse	--
(6) Nickel plate	Acid dip after cyanide copper rinse Semibright nickel or Bright nickel, rinse	for all basis metals in this table						
(7) Chromium plate	Chromium plate, rinse Hot rinse	for all basis metals in this table						

* Also base alloy steels.

TABLE 8. CRITERIA FOR PUBLIC WATER SUPPLIES

Waste Constituents	Permissible Concentrations, ppm
Arsenic	0.05
Beryllium	0.2
Cadmium	0.01
Chromium (hexavalent)	0.05
Copper	1.0
Cyanide	0.01
Gold	0.4
Iron (filterable)	0.3
Lead	0.05
Manganese (filterable)	0.05
Mercury	0.004
Nickel	0.8
Oil and Grease	7
Palladium	7
Phosphates	545
Selenium	10.01
Silver	0.05
Sulfates	250
Tin	1.2
Zinc	5.0

DETAILED PROCESS DESCRIPTIONS

The following section of this report presents additional details of the unit operations and combinations of operations found in the electroplating and metal finishing industry. The unit operations are described in the categories of mechanical, chemical, and electrochemical operations.

Mechanical Operations

Mechanical operations performed in electroplating and metal finishing facilities include abrasive blast cleaning, barrel finishing, grinding, polishing, and buffing.

Abrasive Blast Cleaning

Abrasive blast cleaning entails the forceful direction of abrasive particles--either dry or suspended in a liquid--against the surfaces of metal parts or products, to remove contaminants or to condition the surfaces for subsequent finishing. Abrasive blast cleaning is done to remove dirt, foreign substances, oxide scales, or burrs, or to roughen the surface in preparation for subsequent coating. The particles may be propelled against the workpiece by entrainment in a stream of air or liquid or by means of a rotating impeller wheel. The abrasive materials consist of cast iron or steel grit, cast iron or steel shot, sand, quartz, aluminum oxide, silicon carbide, slag, nut shells, corncobs, sawdust, glass, or plastic beads. Blast cleaning is performed in enclosures which contain the abrasive-propelling device, tables, conveyors or other means of holding or manipulating the workpieces, and means for the collection and recycle of the abrasive, as well as for control of dusts. Blast cleaning may be done on a piece, batch, or continuous basis with manual, semi automatic, or automatic processing and control.

Wet abrasive blast cleaning involves the use of finer (relative to dry blasting) abrasive particles in chemically treated water and is used to produce finer surface finishes than dry blasting. In many cases, wet blasting is preceded by precleaning such as degreasing or dry blasting to prevent the contamination of the wet blasting medium.

Barrel Finishing

The improvement of surface finishes, the removal of burrs, edges or scale, and the formation of radii is specially obtained by tumbling or vibratory finishing of several parts at one time. Just a few large parts may be finished to specification or thousands of small parts may be handled by machines with revolving (tumbling) or vibratory motion. A medium is added to separate the workpieces and perform a finishing operation similar to that in polishing and buffing. Some of the different media which are used are listed in Table 9. Some of the media are used in conjunction with compounds, or compounds are used by themselves. Compounds include sodium cyanide, sodium phosphate, abrasives, burnishing compounds, soaps, wetting agents, silica, or proprietary compounds. Most operations are carried out wet. Equipment may be made of wood or steel and may be lined with neoprene, vinyl, or polyurethane. Metal is removed in the process either as a solid or as dissolved ions depending on the specific compound used. Compounds are lost with each cleaning of the barrel (i.e., at the end of each operation) and are washed into a drain leading to a treatment system, to a neutralization sump where available, or into the sanitary sewer. The media, which have been reduced in size by the abrasive action employed, are washed out with the compounds.

Grinding

Grinding is the application of abrasives to a workpiece to effect the removal of surface material. In metal finishing shops, grinding may be performed to achieve a desired surface finish to remove undesirable material from the surface, to remove burrs or sharp edges, or to achieve close dimensional tolerance.

Grinding equipment includes belts, disks, or wheels consisting of or covered with various abrasives, e.g., silica, alumina, silicon carbide, garnet, alundum, or emery. Grinding equipment may be portable or stationary. Grinding may be with or without the use of lubricants or coolants such as water or water-based mixtures, solutions, or emulsions containing cutting oils, soaps, detergents, wetting agents, or proprietary compounds. Auxiliary equipment associated with grinding operations includes hoods, vents, ducts, and dust collectors, and in the case of wet grinding, tanks, pumps, and pipes for the supply, collection, and recycle of lubricants or coolants.

A special-purpose grinding operation is associated with the deposition of hard-chromium plate. Hard chromium plating is used for finishing parts requiring high wear resistance, such as crankshaft bearings, cam surfaces, dies, gauges, etc. The finishing of such workpieces is done by applying slightly thicker plate than is required, and then grinding to final dimensions. In refinishing worn parts such as those mentioned above, the old chromium plate is removed by grinding, the piece is then plated, and ground to final dimensions.

Polishing and Buffing

Polishing operations are performed for the purpose of achieving an intermediate surface which can be refined further, normally by buffing, prior to plating. The operation may be carried out on metals or nonmetals, and removes some material from the surface. The purpose of buffing is to smooth and brighten the surface without much metal removal.

TABLE 9. MEDIA USED FOR MASS-FINISHING OPERATION[1]

Material	Standard Sizes(a)	Type of Operation	Abrasive Cutting(d) Ferrous	Abrasive Cutting(d) Non-ferrous	Abrasive Cutting(d) Plastics	Barrel Polishing(d) Ferrous	Barrel Polishing(d) Non-ferrous	Barrel Polishing(d) Plastics	Burnishing(d) Ferrous	Burnishing(d) Non-ferrous	Burnishing(d) Plastics
Fused aluminum oxide shapes	#12 mesh to 2 in.	Wet	Y	Y	N	Y	Y	N	N	N	N
Aluminum oxide abrasive powders(b)	#16 mesh and smaller	Wet or dry	Y	Y	y	Y	y	y	N	N	N
Bonded abrasives	1/16 to 2 in.	Wet	Y	y	y	Y	y	N	N	N	N
Ceramic bonded aluminum oxide	1/16 to 2 in.	Wet	Y	y	N	Y	y	N	N	N	N
Granite (mica-schist) chips(c)	1/16 to 1-1/4 in.	Wet	Y	Y	N	y	y	N	N	N	N
Flint stone(c)	1/16 to 2 in.	Wet	Y	Y	oy	y	y	N	N	N	N
Quartzite(c)	Various	Wet	Y	Y	N	y	y	N	N	N	N
Marble(c)	Various	Wet	Y	Y	N	y	y	N	N	N	N
Limestone chips(c)	1/16 to 1-1/4 in.	Wet	Y	Y	oy	Y	y	N	N	N	N
Sand (sharp, builder's)	#8 mesh and finer	Wet or dry	Y	Y	oy	Y	y	oy	N	N	N
Rolled zinc slugs	Various	Wet	yW	yW	N	YW	YW	N	Y	Y	N
Die-cast zinc slugs	Various	Wet	yW	yW	N	YW	YW	N	Y	Y	N
Soft steel balls and shapes	1/8 to 1/2 in.	Wet	yW	yW	N	YW	YW	N	Y	Y	N
Wooden balls and shapes	Various	Wet or dry	yW(f)	yW(f)	YW	yW(f)	yW(f)	YW	Y(f)	Y(f)	Y(f)
Vegetable ivory chips	Various	Wet or dry	yW(g)	yW(g)	N	yW(g)	yW(g)	N	Y	Y	N
Nut shells	Mixed sizes	Usually dry	N	N	YW	yW	yW	Y	Y	Y	Y
Hard steel balls and shapes	1/64 to 1/4 in.	Wet	N	N	N	N	N	N	Y	Y	N
Glass burnishing balls	New product	Wet	N	[illegible]	N	N	N	N		Y	
Macerated corn cobs(e)	Mixed-dust free	Dry	N	[illegible]	N	N	N	N	Y	Y	Y
Leather scrap	Various	Wet or dry	N	[illegible]	N	N	N	N	Y	Y	Y
Felt scrap	Various	Dry	N	[illegible]	N	N	N	N	Y	Y	Y
Molded iron powder and abrasive	New product	Wet	Y	Y		Y	Y		N	N	N

(a) Usual average dimensions. Other sizes available for special applications.
(b) Although occasionally used alone, particularly with parts which can be said tumbled, this grain is usually mixed with other media.
(c) Available in quarried state or processed to remove sharp corners. Quarried form is only good for very roughest of operations and becomes processed form after few hours of use.
(d) Symbols indicate as follows:

Y = most usual use
y = often used or possible use
N = never used
YW or yW = used with added fine abrasive
oy = occasionally used for special applications.

(e) Also used for drying after polishing or burnishing of all metals and plastics and as medium extender for all media to reduce harsh action.
(f) With or without other media.
(g) See wood balls.

Polishing is carried out on hard-faced wheels varying in diameter, thickness, and material depending upon the part that is being processed, the finish, and the material-removal rate desired. Wheels are constructed of woven cotton fabrics, canvas, felt, or leather disks glued or sewn together, or a combination of glued and sewn discs. Felt wheels are used where true surfaces are required or where a contoured shape is being finished. Leather wheels produce a finer finish, and wood wheels covered with leather are normally used for flat surfaces. Abrasives are generally applied to these wheels with synthetic adhesives or cements which have generally replaced the hide glue formerly used. The ratio of abrasive to glue used in the facing of the wheels changes with grit size. Used wheels may be recoated after removal of lubricants from the facing or the facing itself may be replaced. The abrasives are fused aluminum oxide, silicon carbide, and turkish emery. Tallow, grease, special bar lubricants, and spray lubricants are also used. Woven cloth belts are also used for polishing operations after having been treated in the same way as the wheels. Greaseless polishing can be accomplished with flexible polishing wheels using softer cloths. Burrs on castings or stampings may also be removed with the use of polishing wheels.

Buffing normally follows the polishing operation as the last step before plating. Depending on the desired finish of the product, the operations may vary. Satin finishes are obtained using fast cutting abrasives, mostly aluminum oxide and silicon carbide, combined with glue or adhesive binders to form a greaseless compound buffing bar. Grease-base buffing bars are made of animal, vegetable, and mineral fats and waxes together with an adhesive. "Cut-down" buffing bars are composed of various materials, depending on the metal to be finished. Once-ground Tripoli and aluminum oxide are most widely used. An operation known as "cut-and-color" buffing is used in place of the cut-down operation to achieve a small amount of metal removal while at the same time giving some luster to the metal. Basically, the same constituents are used in different compositions to produce cut-and-color bars. Red iron oxide powder is frequently used for nonferrous metals. For producing a final finish having the best color and luster, very small amounts of very fine abrasives are used consisting of the materials listed above plus bars containing chromium oxide for finishing stainless steel and chromium plate.

Where semiautomatic or automatic polishing machines are used, the buffing compound is not in a bar form but is applied in a liquid form from air pressure feed tanks or circulating drum pumping equipment. The newest development is a system of airless spray buffing. Liquid compounds are also available for manual buffing operations. The same abrasives are used as in buffing bars, but the vehicle materials are oil solutions or water emulsions instead of grease, fat, waxes, and oils. Liquid buffing compounds, besides achieving a better finish at a lower cost than manual operations with bar compounds, are required in smaller amounts, cause less wear on the buffing wheel, and cause less dirt to be packed onto the parts for easier subsequent liquid cleaning. The different production techniques are summarized in Table 10.

TABLE 10. PRODUCTION TECHNIQUES FOR THE POLISHING AND BUFFING OF METAL[a]

Material Finished	Polishing		Satin	Buffing	
	Rigid	Flexible		Cutdown	Color
Aluminum	Glue or cold cement headed with aluminum oxide abrasive; grease bar applied to wheel; sewed buff; canvas, felt, or leather wheel.	Aluminum oxide greaseless compound, tripoli bar applied to greaseless compound head. Loose or sewed buffs.	Aluminum oxide greaseless compound, light head of dry tripoli bar. Loose or ventilated buff or string wheel.	Tripoli bar or liquid compound. Loose or ventilated buff.	Rouge, silica, unfused aluminum oxide bar or liquid compound. Loose or low-density ventilated buff.
Brass	Glue or cold cement headed with aluminum oxide abrasive; grease bar applied to wheel; sewed buffs; canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Sewed or loose buffs, canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or ventilated buff. String wheel.	Tripoli bar or liquid compound. Ventilated. Loose or sewed buffs.	Rouge, silica, or unfused aluminum oxide bar or liquid compound. Loose or low-density ventilated buff.
Hard Chromium	Silicon carbide greaseless compound over glue sizing. Sewed buff. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or sewed buffs. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose buff.		Chrome green oxide or unfused aluminum oxide bar or liquid compound. Loose or ventilated buff.
Chromium Decorative Plate			Lubricated silica greaseless compound. Loose buff.	(Not usually needed) combination [illegible] fused and unfused aluminum oxide bar. Loose or ventilated buff.	Chrome green oxide unfused aluminum oxide bar or liquid compound. Loose or ventilated buff.
Copper		Aluminum oxide greaseless compound. Loose or ventilated buff string wheel	Aluminum oxide greaseless compound. Loose or ventilated buff. String wheel.	Tripoli bar or liquid compound. Loose, sewed, or ventilated buff.	Rouge, silica, or unfused aluminum oxide or liquid compound. Loose or low-density ventilated buff.
Copper Plate			Aluminum oxide greaseless compound. Loose or packed buff. String wheel.	Tripoli bar or liquid compound. Loose, sewed, or ventilated buff.	
Nickel and Nickel Alloys	Glue or cold cement headed with aluminum oxide abrasive; sewed buff. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or sewed buffs. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or ventilated buff.	Tripoli bar or liquid compound. Loose, sewed, or ventilated buff.	Chrome green oxide or unfused aluminum oxide bar or liquid compound. Loose or ventilated buff.
Nickel Plate Decorative			Aluminum oxide greaseless compound. Loose or ventilated buff.		Lime bar, or chrome green oxide, or unfused aluminum oxide bar or liquid compound. Loose or low-density ventilated buff.
Steel and Stainless Steel	Glue or cold cement headed with aluminum oxide. Grease bar or energy cake applied to wheel. One or more operations required. Sewed buff; canvas, leather, or felt wheels.	Silicon carbide or aluminum oxide greaseless compound. Loose or sewed buffs. Canvas, felt, or leather wheels.	Silicon carbide or aluminum oxide greaseless compound. Loose or ventilated buff.	Aluminum oxide bar or liquid compound. Ventilated, sewed, sisal finger, or [illegible] buff.	Chrome green oxide and/or unfused aluminum oxide bar or liquid compound. Loose or ventilated buff.
Zinc		Aluminum oxide greaseless compound. Loose or sewed buffs.	Aluminum oxide greaseless compound. Loose or ventilated buff.	Tripoli bar or liquid compound. Loose, ventilated, or sewed buff.	Silica or unfused aluminum oxide and/or liquid compound. Loose or low-density ventilated buff.

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[a] Metal Finishing Guidebook and Directory, 1974, p. 128-129, Metals and Plastics Publications, Inc., Hackensack, New York.

NOT REPRODUCIBLE

Chemical Processes

Processes used in the electroplating and metal finishing industry which involve chemical action (as compared to electrochemical action) include degreasing, alkaline cleaning, acid treatments, chromating, phosphating, passivating, bright dipping, chemical polishing, and electroless nickel plating.

Degreasing

Degreasing, also referred to as solvent cleaning, involves the application of a solvent or solvent mixture to remove oil and grease from the workpiece. Two methods of degreasing are practiced: vapor degreasing in which the workpieces are suspended in the vapor phase of a boiling solvent and dip, or cold cleaning, in which the workpieces are immersed in the solvent.

Equipment for vapor degreasing includes a tank with heating coils at the bottom. The tank is divided into a liquid solvent region, and a solvent vapor region. A cooling zone is at the top of the tank to condense the rising vapor. For cold cleaning a simpler tank is required. Auxiliary equipment for both degreasing methods includes hoists, racks, barrels, or conveyors for manipulating the work into and out of the degreaser tank, and an appropriate heat supply, ventilation and fume collection system. Auxiliary equipment may also include means for recovery of the solvent. The vapor degreaser tank itself may be used as a still to distill off the pure solvent, the residue being removed from the tank, and the tank refilled with the pure solvent. A separate still may be used to separate the pure solvent from the residue, and may be operated on a batch or continuous basis.

The solvents used for vapor degreasing operations are characterized in Table 11.

Alkaline Cleaning

The purpose of alkaline cleaning is to remove dirt, greases, oils, and other foreign material from the surface of the workpiece. Alkaline cleaning involves the application of aqueous solutions of sodium compounds such as carbonate, phosphate, silicate, or hydroxide with or without additions of surfactants, or chelating agents. Most alkaline cleaning solutions are based on proprietary compounds. Ranges of cleaning solution compositions and operating conditions are given in Table 12. Alkaline cleaning may also be performed as an electrochemical process in which the workpieces are made either the anode or cathode of an electrochemical circuit. When the workpiece is made the cathode, hydrogen is evolved at the surface of the workpiece; when the workpiece is made the anode, oxygen is evolved at its surface. The gas evolution aids in the cleaning action.

TABLE 11. TYPICAL APPLICATIONS FOR VAPOR-DEGREASING SOLVENTS[(1)]

Application	Solvent	Approximate Vapor Temperature, F	Factors Affecting Selection
Removal of soils from parts	Trichlorethylene	183	Most commonly used degreasing solvent
Removal of slightly soluble (high melting) soils	Perchlorethylene	250	Used where higher operating temperature is desirable
Removal of water films from metals	Perchlorethylene	250	Rapid and complete drying in one operation
Cleaning coils and components for electric motors	Methyl chloroform Trichlorotrifluoroethylene	165 118	Solvent must not damage wire coating or sealing agents. Requires special equipment design. Selection should be based on preliminary trials.
Cleaning temperature-sensitive materials	Methylene chloride Trichlorotrifluoroethylene	104 116	Used where parts must not be exposed to higher vapor temperatures during cleaning. Special corrosion resistant equipment is required.
Cleaning components for rockets or missiles	Trichloroethylene	188	Cleaned parts must be free of soils or residues which might react with oxidizers.
Cleaning with ultrasonics	Trichlorethylene Perchlorethylene Methylene chloride Fluorinated hydrocarbon	188 250 104 118	For cleaning efficiency beyond that obtained from standard vapor degreasing. Solvent must be kept clean by continuous distillation and filtration during use. Selection should be based on preliminary trials.

(1) Metal Finishing Guidebook and Directory, 1972 Edition, Metals and Plastics Publishing, Inc. Hackensack, New Jersey.

TABLE 12. ALKALINE CLEANING SOLUTIONS AND OPERATING CONDITIONS(2)

Constituent or Condition	For Ferrous Metals	For Copper and Brass	For Aluminum
	Composition, grams/liter		
Sodium Carbonate, Na_2CO_3	30-45	12-22	23
Trisodium Phosphate, $Na_3PO_4 \cdot 12H_2O$	15-30	8-18	23
Sodium Hydroxide, NaOH	7.5-15	3-12	
Surfactant		0.3-0.5	
	Operating Conditions		
Current Density, mA/cm^2	30-60	10-30	
Time as Cathode, min.	1-2	1-3	
Time as Anode, sec.	15-30	5-10	
Soak Time, min.			1-3
Temperature, C	at least 90	60-70	60-80

The equipment required for alkaline cleaning includes tanks, either electrical or steam heat, temperature control devices, hoists, rack barrels, or conveyors for moving the workpieces. In the cases of anodic and cathodic alkaline cleaning, an electrical power source, leads, and contacts are also required.

Acid Treatments

Treatment of the surface of the workpieces with acid solutions is performed for oxide removal or for the neutralization of the residual alka films. The removal of oxide films is usually referred to as either picklin or bright dipping. The term pickling denotes the removal of relatively thick oxide films and usually includes the removal of some metal. The term bright dipping denotes the removal of relatively thin oxide or tarnish films with no significant removal of metal. Pickling is usually performed as a preparatory step before finishing, while bright dipping is usually an intermediate or final step in a finishing process sequence. Some acid treatments, basis materials, and acid concentrations are illustrated in Table 13.

Equipment for acid treatments includes tanks with acid resistant linings such as lead, rubber, glass, or acid-resistant brick, provisions for heating and temperature control, and equipment for moving the work int and out of the acid solution such as hoists, conveyors, hangers, racks, barrels, etc.

Chromating

The purpose of chromating is to develop a protective film on the surface of the metal being treated. The process involves the immersion of the metal in an aqueous solution of chromic acid or chromium salts so that some of the metal is dissolved and a film containing complex chromium compounds is formed on the surface of the metal. Because of the sequence of dissolution followed by film formation, chromating is referred to as a conversion coating. Chromate coatings are usually applied in a final processing step to enhance the corrosion resistance or appearance of metals and electroplated metals including zinc, cadmium, magnesium, and aluminum. They are also used as coatings to enhance the adhesion of subsequently applied paint. Chromate coatings may be clear or may be produced in a variety of colors, including olive green.

Most chromating solutions are made up using proprietary componen Published data indicate that chromating solutions contain 2 to 35 mg/1 of hexavalent chromium supplied in the form of chromic acid or salts such as potassium chromate or dichromate. The solutions also contain other anions such as sulfate, nitrate, chloride, or fluoride.

Equipment for chromating includes tanks, tank linings, and heati coils of ceramics, acid-resistant brick, stainless steel, asphalt compound plastics, quartz, or carbon. Chromating can be performed by dipping, spraying, or brushing, using manual rack, barrel, or automatic procedures.

TABLE 13. SOME ACID TREATMENTS USED FOR PICKLING, CLEANING, AND BRIGHTENING

Purpose	Material	Acid	Acid Concentration, wt %	Operating Temperature, C	F
Pickling	Steel	Sulfuric	5-16	Room-82	Room-180
Pickling	Steel	Hydrochloric	-	Room-56	Room-130
Pickling	Steel	Phosphoric	-	-	-
Pickling	Steel	Nitric	6-8	-	-
Pickling	Copper Alloys	Sulfuric	5-10	Room-79	Room-175
Bright-ening	Copper Alloys	Sulfuric- Nitric	0-100 0-100	-	-
Bright-ening	Copper Alloys	Phosphoric- [illegible] [illegible]	10-60 [illegible] [illegible]	[illegible]	[illegible]
Acid Cleaning	Aluminum Alloys	Chromic- Sulfuric	[illegible] 15-19	43-82	110-180
Acid Cleaning	Aluminum Alloys	Nitric- Hydrofluoric	50-75 5-38	Room	Room
Acid Cleaning	Aluminum Alloys	Phosphoric- Chromic	14 4	43-66	110-150
Bright-ening	Aluminum Alloys	Phosphoric- Nitric	45-99 0.5-50	88-110	190-230

Chromating processes are usually preceded by water rinses or acid dips and are usually followed by rinses. Bleaching or dying of the chromate coatings may be performed by immersion in the appropriate solutions. Chromate coatings almost always require drying at temperatures up to a maximum of 71 C (160 F) using air blasts from forced hot air ovens or other means.

Phosphate Coating

Phosphate coating is the treatment of a metallic surface with a dilute solution of phosphoric acid and other chemicals to produce a coating of insoluble, crystalline phosphate compounds. These coatings commonly serve as a base for subsequent coatings of paint, oil, or wax, or serve to improve corrosion and wear resistance, or as an aid in forming processes. Phosphate coatings are commonly applied to ferrous materials, zinc, and cadmium, are usually applied in thicknesses from 0.00025 to 0.005 centimeters (0.001 to 0.002 inch); they vary in color from light gray to black. Phosphate coating solutions are generally based on proprietary mixtures.(1-3) Published information indicates that the solutions contain phosphoric acid, phosphates of iron, zinc, or manganese, plus compounds which act as oxidizers or accelerators. Phosphate coating solutions are usually operated at temperatures of [illegible] [illegible] which results in improved corrosion resistance.

Phosphate coatings are applied by brush, spray, or immersion methods using manual or automatic machine techniques which may be applied to single or batch lots of workpieces. Equipment used for phosphate coating includes tanks or spray cabinets, buckets, barrels, racks, hooks, hoists, conveyors, and heating and temperature control apparatus. Associated operations usually include drying in air blasts or controlled-temperature, forced-air ovens, and these may be followed by the application of paints, oils, or waxes by spraying or dipping.

The application of phosphate coatings involves the consumption of phosphoric acid in the coating reaction and characteristically generates a sludge of reaction products which accumulates in the bottom of the process tanks or in sumps in the spray systems. The sludge must necessarily be periodically removed.

Passivating

Passivating treatments are performed almost entirely on stainless steel to develop a uniform and protective oxide film on the workpiece. Passivating treatments involve the immersion of stainless steel [illegible] [illegible] may or may not be added to the solution). The passivating treatment dissolves foreign substances such as lead, copper, cadmium, or imbedded iron particles remaining from prior forming, machining, tumbling, or wire drawing operations. The foreign material, if not removed, could result in an irregular protective oxide coating, associated rust spots and selective corrosive attacks. Passivation is usually preceded by an appropriate cleaning process such as any of the mechanical cleaning processes, degreasing, or alkaline cleaning. Because of the need for uniform treatment of surfaces, passivating is performed by dipping.

Equipment associated with passivating operations includes tanks of suitable material (i.e., stainless steel, aluminum, or other acid-resistant material), heating and temperature control apparatus, materials handling equipment such as hoists, hooks, racks, buckets, or barrels, and hooding and ventilating equipment. Passivating solutions are depleted during use by reaction of the nitric acid and drag out and may be replenished by addition of nitric acid.

Bright Dipping and Chemical Polishing

Bright dipping and chemical polishing solutions usually consist of mixtures of two or more acids such as sulfuric, nitric, hydrochloric, phosphoric [illegible] and smoothing of the surface the process may be termed bright dipping or chemical polishing.

Most processes are applied to nonferrous metals and are most extensive with aluminum, where mixtures of phosphoric and nitric acid are used with additions of acetic or sulfuric acid. The metal removal in aluminum dipping may vary from 0.0025 to 0.05 µm (0.0001 to 0.002 inch). Copper and copper alloys are bright dipped in sulfuric acid to which an oxidizing agent is added. Chromic acid, dichromates, ferric sulfate and nitric acid are useful. The rate of attack on the metal varies with acid concentration, the amount of oxidizing agent and inhibitor used from 0.025 to 0.2 µm (0.0001 to 0.01 inch). Racked work can be carried out in the more concentrated bath, while bulk parts are dipped in diluted solutions where the rate of attack is slower. Phosphoric-nitric-acetic acid solutions are used for chemical polishing. The attack on the copper is slower than with the bright dipping solutions and a smoothing action results which gives a higher luster. Bright dips for ferrous metals contain hydrogen peroxide or are composed of mineral acids with small amounts of inhibitors. Phosphoric-sulfuric-nitric acid solutions are used for nickel-alloys, while cadmium and zinc are bright dipped in chromate and dilute nitric acid solutions; or in peroxide solutions. A sodium cyanide-peroxide solution is often used for dipping silver and a peroxide-acetic acid solution finds application with lead. In addition, a large number of proprietary solutions are on the market for bright dipping and chemical polishing for ferrous and nonferrous metals and alloys.

Electroless Nickel Plating

Electroless nickel plating is a process in which an aqueous solution of nickel and other compounds undergoes a catalytic decomposition, resulting in the deposition of a nickel coating on the surface of the workpiece. Electroless nickel coatings are deposited on the workpiece to increase corrosion resistance, dimensional build-up, and wear resistance, to facilitate subsequent soldering or brazing operations, or to produce a metallic coating on ceramics, plastics, or special metals not readily electroplated. The catalytic nature of the electroless nickel plating process has associated with it requirements for careful surface preparation of the material to be coated, complex solution composition, the requirement for close control of operating conditions, and, for continuous operations, extensive auxiliary equipment for solution make up and purification.

Characteristics of various electroless nickel plating baths are listed in Table 14. The reactions which occur in the electroless nickel plating bath include the following:

1. The hypophosphate ions change to orthophosphite ions with the formation of hydrogen;
2. The hydrogen thus formed acts to reduce the nickel from the ionic state to the metallic state; and
3. Some hydrogen also reacts with the hypophosphite to produce elemental phosphorus.

The overall results of these reactions are that nickel containing 3 to 15 percent phosphorus is deposited on the surface of the workpiece while the pH of the solution decreases. The nickel is depleted from solution and hypophosphite is oxidized. The original solution is metastable and its rate of decomposition is sensitive to temperature and to other variables. If the decomposition of the solution proceeds too rapidly, nickel is rejected throughout the volume of the bath rather than only at the surface.

One of the advantages characteristic of the electroless nickel plating process is that it may be used on very large workpieces such as tanks by using the workpiece as the container for the solution.

Equipment required for electroless nickel plating may vary from a single vessel to the components discussed below in the discussion of a continuous process. Tank linings are usually inert materials such as tetrafluoroethylene or a phenolic-base organic. Heat supply and temperature control are required as are means for pH control, and controlled agitation achieves uniform patterns of escape of hydrogen gas. Heating is usually achieved by a heating jacket on the tank rather than immersed electrical or steam coils.

In continuous operations, the plating tank is part of a circuit that includes:

1. A storage tank, in which a prepared solution is stored or in which final adjustments or additions may be made;

TABLE 14. RANGES OF COMPOSITIONS OF ELECTROLESS NICKEL PLATING SOLUTIONS(3)

Constituent	Concentrations, g/liter Alkaline Baths	 Acid Baths
Nickel Chloride	30-45	30
Nickel Sulfate	None	15-21
Sodium Hypophosphite	10-11	10-27
Ammonium Chloride	50	None
Sodium Citrate	1-100	None
Ammonium Citrate	0-65	None
Ammonium Hydroxide	*	None
Sodium Acetate	None	0-13
Sodium Hydroxyacetate	None	0-50
Sodium Succinate	None	0-16
Lactic Acid	None	0-34**
Propionic Acid	None	0-10**
pH***	8-10	4-6
Temperature, C	91-96	88-99

* Added in amounts sufficient to achieve the proper pH.

** Given in ml/liter.

*** pH reported in pH units.

- a heat exchanger, through which the used plating solution is passed to adjust the temperature of the solution to the plating temperature;

- a plating tank;

- a heat exchanger, through which used plating solution is passed to cool the solution to 79 C or below before regeneration;

- a regeneration tank, where reagents are added to restore the solution to the desired composition; and

- a filter, or a settling tank and a filter to remove any solids precipitated during the regeneration step.

The circuit may also contain a tank or crystallizer in which the solution is cooled to remove any excess sodium sulfate before it is returned to the storage tank.

Auxiliary equipment associated with electroless nickel plating operations includes appropriate means of handling the workpieces such as hooks, racks, barrels, or buckets, as well as hoists or conveyors. Because of the nature of the process, special measures are usually taken to insure uniform escape of the hydrogen gas and uniform deposition of the coating such as controlled oscillation, vibration, or rotation of the workpieces.

Electroplating Processes

Electroplating operations performed in electroplating and metal finishing facilities include nickel, chromium, cadmium, zinc, copper, tin, iron, gold and silver plating as the most important processes. Alloys may be deposited from solutions with compatible anions; other metals such as indium, rhodium, platinum, and cobalt are used to a very small degree in metal finishing. Anodizing is used most often for aluminum.

Nickel Plating(1-4)

Nickel is one of the more important metal coatings applied by electroplating. Nickel plate, with or without an underlying copper strike plate, is primarily employed as a bright coating underneath a comparatively thin chromium electroplate to provide a decorative and corrosion-protective coating for parts of steel, brass, zinc, and other basis metals. Nickel, by itself, is electrodeposited on steels and other basis metals to provide decorative and corrosion-resistant finish. Heavier nickel deposits are frequently employed to build up worn parts or provide wear-resistant surfaces. Nickel electrodeposition is used extensively to electroform intricate-shaped articles that would be difficult or expensive to fabricate by conventional metal-working or machining methods.

Nickel is generally electroplated from Watts (sulfate-chloride-boric acid), sulfamate, fluoborate, and chloride baths. Typical compositions and operating conditions for general-purpose nickel plating baths are given in Table 15.

When nickel is plated directly on the basis metals, the basis metal surfaces are generally first cleaned, rinsed, and then acid dipped and rinsed prior to nickel plating. The basis metals are frequently copper plated prior to nickel plating. Such a procedure is almost always employed with zinc and zinc alloy parts. After copper plating, the parts are rinsed, acid dipped, rinsed, nickel plated, rinsed, and then dried. Table 5 illustrates the different plating operations performed for the different basis metals. A representative sequence of steps used for applying a triple electroplate (Cu-Ni-Cr) on steel, brass, or zinc parts is shown in Table B-2 in Appendix B.

Nickel can be electrodeposited in still tanks, barrels, and in a variety of automated equipment. Typical tank linings for nickel baths include PVC, natural rubber, neoprene, and Saran. External heating or cooling of nickel baths can be carried out in heat exchangers made of heat-resistant glass or cast graphite. For internal heating elements, impervious graphite and glass coils are satisfactory.

The major source of nickel chemical waste is from the drag out into the rinse waters. Solution leakage from filters, pumps, and pipes is a seconary source of nickel wastes, with accidental spills and poor housekeeping contributing some additional wastes. Nickel plating baths are rarely dumped.

Chromium Plating(1-4)

There are two principal types of chromium plating, i.e., decorative and hard. In decorative plating, a thin chromium coating serves as a protective, nontarnishing, durable surface finish. It is difficult to obtain dense pore-free chromium deposits, and therefore, chromium is generally applied over coatings of copper plus nickel, or nickel alone. These metals have greater ductility and good corrosion resistance. Typical decorative chromium plate thicknesses over copper-nickel or nickel undercoats range from $2.5(10^{-5})$ to $5(10^{-5})$ cm [$1(10^{-5})$ to $2(10^{-5})$ inch]. In hard (also known as "industrial" or "engineering") chromium plating, heavier coatings are used to take advntage of the special properties of chromium plating, heavier coatings are used to take advantage of heat and corrosion. Unlike decorative chromium plating, hard chromium is generally applied to the basis metal without an intermediate coating. Hard chromium is normally deposited to thicknesses ranging from $2.5(10^{-4})$ to $5.1(10^{-2})$ cm [$1(10^{-4})$ to $2(10^{-2})$ inch] and even more in some applications.

Typical parts coated with decorative chromium include: exterior and interior automotive parts; boat hardware; household appliances; home, office, and school furniture; plumbing fixtures; bicycle hardware; and cabinet hardware. Representative applications for hard chromium plating

TABLE 15. TYPICAL BATH COMPOSITIONS AND OPERATING CONDITIONS FOR NICKEL PLATING OPERATIONS(1,3)

Constituent or Operating Condition	Watts Bath(a)	Sulfamate Bath(a)	Fluoborate Bath(a)	All Chloride Bath(a)
Composition, grams/liter				
Nickel sulfate, $NiSO_4 \cdot 6H_2O$	225 - 413	--	--	--
Nickel chloride, $NiCl_2 \cdot 6H_2O$	30 - 60	0 - 30	0 - 15	70
Nickel sulfamate, $Ni(SO_3NH_2)_2$	--	263 - 450	--	--
Nickel fluoborate, $Ni(BF_4)$	--	--	225 - 300	--
Total nickel as metal	58 - 107	62 - 113	58 - 79	17
Boric acid, H_3BO_3	30 - 45	30 - 45	15 - 30	30
Operating Conditions				
pH	1.5 - 5.2	3 - 5	2.5 - 4	~1.0
Temperature, C	46 - 71	38 - 60	38 - 71	~ 55
Current density, amp/sq cm	0.011 - 0.110	0.027 - 0.324	0.027 - 0.324	0.054 - 0.108

(a) Small amounts of surfactants, wetting agents, or other addition agents may be added to the baths to prevent pitting, refine grain structure, or brighten plates, etc. Many of these addition agents are specially developed proprietary compounds.

include: restoration to original dimensions of worn, mismachined, or undersized parts; coating of tools, dies, and gauges and other parts to minimize wear and to reduce galling, friction, and corrosion; coating of electrotypes, engraving plates, and other items intended for prolonged runs.

Conventional chromium plating solutions contain chromic acid and a small amount of sulfuric acid or a mixture of sulfuric acid and fluosilicate or fluoride ions. The ratio of the concentration of the chromic acid to the catalyst acid radicals or anions ranges from about 50:1 to 250:1, and preferably should be about 100:1. Typical chromium plating bath compositions and operating conditions are given in Table 16.

Chromium can be electroplated in still tanks, barrels, and in automatic equipment. Tanks for chromium plating are usually steel tanks lined with materials such as fiberglass-reinforced plastics, PVC, or lead alloy (6% Sb) sheet. Plastic linings are generally preferred with the proprietary fluoride-containing baths. Insoluble lead alloy anodes are almost always used in chromium plating from chromic acid baths. For conventional sulfate baths, lead-antimony (6-8% Sb) alloy is preferred, while for fluoride-containing baths lead-tin (4-7% Sn) alloy is recommended. Solutions are frequently heated or cooled by lead-alloy coils inside the tanks. Tantalum coils and heat exchangers are now being used more extensively because of their long life and efficient operation.

Table 4 illustrates the different plating operations performed for the different basis metals. A typical sequence of operations for the application of chromium over copper-nickel undercoats on steel and brass parts is shown in Appendix B, Table B-2, Line 2. The sequence of steps involving cleaning and anodic activating treatments used prior to applying hard chromium on steel parts is shown in Appendix B, Table B-2, Line 6.

Drag out of the plating solution into the rinse waters is the major source of chromium wastes. Spray carried from the solution by the hydrogen and oxygen gases generated at the electrodes is a secondary source of waste. Scrubbers installed in the exhaust system on the tanks can recycle most of the spray or collect it for transfer to the waste treatment system. Dumping of chromium plating solutions is not normally practiced.

Cadmium Plating(1-4)

Cadmium plating is used extensively to provide an attractive corrosion-protective coating over various basis metals, especially steel and cast iron. Cadmium, being anodic to iron, provides protection to the basis metal even though the cadmium coating is nicked or scratched. The relatively high cost of cadmium generally restricts its application to thin coatings [less than 25 μm (1 mil) thick] on parts used indoors or in sheltered positions outdoors; however, the use of cadmium for aircraft, marine, and military outdoor applications are common. Cadmium is frequently employed to coat parts or assemblies made up of dissimilar metals to minimize corrosion. Cadmium's excellent solderability and low contact resistance also make it attractive for electrical industry uses.

TABLE 16. TYPICAL BATH COMPOSITIONS AND OPERATING CONDITIONS FOR CHROMIUM PLATING(1-4)

Constituent or Operating Condition	Bath No. 1	Bath No. 2	Bath No. 3	Bath No. 4
		Composition, grams/liter		
Chromic acid, CrO_3	250	400	340	175
Sulfuric acid, H_2SO_4	2.5	4.0	2.2	1.4
Fluoride ion, F^{-1}	--	--	--	0.7
		Operating Conditions		
Temperature, C	43-49	43-49	54	43-54
Current density, amp/sq cm	0.11-0.23	0.11-0.23	0.16-0.38	0.16-0.46

Most cadmium plating is done in cyanide solutions. Typical bath compositions, operating conditions, and features of the cyanide and fluoborate baths are shown in Table 17. Grain refiners and brighteners in the cyanide baths can be metallic, such as nickel, cobalt, molybdenum or selenium, or organics such as coumarin, gelatin, sugars, sulfonic acid derivatives, and aromatic aldehydes. Licorice is suggested for use in the fluoborate bath. Most additives are proprietary compounds or mixtures.

Pretreatment of basis metals prior to cadmium cyanide plating generally consists of cleaning, acid dipping, rinsing, and cyanide or caustic dipping. The pretreatment is similar when fluoborate baths are used except an acid rinse is employed rather than caustic. After plating the parts are rinsed. Although in many instances the cadmium-plated parts are shipped without further treatment, often a post treatment is employed. The simplest treatment is a bright dip carried out in a dilute solution of nitric acid or chromic acid. Chromate conversion coatings are often applied to cadmium plated parts for applications where it is desired to minimize "white rust" or to enhance paint adhesion. A processing sequence for cadmium plating-chromating steel parts in a manual-barrel operation is shown in Table B-2, Line 5 in Appendix B.

For plating cadmium from cyanide solutions unlined steel tanks are generally employed. Lined tanks usually are used for cadmium fluoborate baths. Plating can be done manually or automatically using racks or barrels. Both soluble and insoluble anodes are used with the cyanide baths. Ball-shaped cadmium anodes in a spiral cage holder of bare steel are used in cyanide baths. Insoluble anodes generally are made of low-carbon steel strips. Bar-type cadmium anodes are used in the fluoborate baths.

The major source of cadmium-solution wastes is from the drag out into the rinse waters. A secondary source can be solution leakage from filters, piping, and pumps. Accidental spills and poor housekeeping can also contribute to the cadmium waste load. Dumping of cadmium plating baths is not commonly practiced.

Zinc Plating(1-4)

Zinc coatings are generally applied to the workpiece to protect iron and steel parts against corrosion. Zinc, being anodic to iron and steel, offers more protection at a smaller cost when applied in thin films than similar thicknesses of nickel or other cathodic coatings. Because zinc is relatively inexpensive, and readily applied in tank, barrel, or continuous plating facilities, it is frequently the preferred coating for most ferrous parts for protection against atmospheric and indoor corrosion.

The majority of fabricated steel parts that are zinc plated are plated in cyanide baths. The use of acid zinc baths is largely restricted to the plating of mill products, such as wire, strip, sheet, and conduit. Typical compositions and operating conditions for zinc cyanide plating baths are given in Table 18. During the past five years the use of noncyanide alkaline solutions, prepared with zinc pyrophosphate or another chelating agent such as tetrasodium phosphate, sodium citrate, or the

TABLE 17. REPRESENTATIVE COMPOSITIONS AND OPERATING CONDITIONS FOR CADMIUM PLATING BATHS(3,4)

Solution	Composition, grams/liter					Current Density(a) Range, amp/sq cm	Operating Temperature, C	Remarks
	Cadmium Oxide	Cadmium Metal	Sodium Cyanide	Sodium Hydroxide	Sodium Carbonate			
				Cyanide Solutions				
1	22.5	19.7	78.0	14.3	30-75	0.005-0.065	27-32	Used for still plating; good efficiency, fair throwing power; also used in bright barrel plating
2	22.5	19.7	138	14.3	30-45	0.011-0.086	27-32	Used for still and automatic plating; high throwing power, uniform deposits, fair efficiency; not for barrel plating
3	26.3	23.0	115	16.4	30-60	0.005-0.097	24-30	Used mostly for still plating, but can be used for barrel and automated plating; high efficiency, good throwing power and deposit uniformity
4	41.3	36.2	163	25.8	30-45	0.005-0.162	27-32	Used for high speed-high efficiency plating; used for plating on cast iron
				Fluoborate Solution				
	Cadmium Fluoborate	Cadmium Metal	Ammonium Cyanide	Boric Acid	Licorice			
5	242	94.5	60.0	27.0	1.0	0.032-0.65	21-32	Used mostly for barrel plating; adaptable to plating of strip and wire

(a) For good uniform deposits from the cyanide solutions a current density of 0.022 to 0.043 amp/sq cm is recommended.

TABLE 18. TYPICAL ZINC CYANIDE PLATING BATHS[a] [2-4]

Constituent or Condition	Plating Method		
	Barrel	Still Tank or Automatic	Conduit Tubing or Strip
	Composition Ranges, grams/liter		
Zinc cyanide	60-83	60-83	60-90
Sodium cyanide	39-66	32-66	16-49
Sodium hydroxide	75-90	75-90	75-90
Sodium polysulfide	1.5	1.5	1.5
	Operating Conditions		
Temperature, C	20-35	20-35	32-49
Current density, amp/sq cm	0.003-0.011	0.016-0.054	0.043-0.108

(a) Organic or metallic brighteners are generally employed in zinc plating baths; most brighteners used in industry are proprietary formulations.

sodium salt of ethylene diamine tetraacetic acid, has increased to avoid dealing with the cyanide waste problem.

Typical pretreatment of the basis metals (mostly ferrous materials) prior to zinc cyanide plating generally consists of (a) electrolytic cleaning, (b) rinsing, (c) acid pickling, (d) rinsing, and (e) cyanide or caustic dipping. Where no posttreatment is employed, the zinc plated parts are first rinsed in cold water, then rinsed in hot water and air dried. In some instances, the zinc plated parts are given a bright dip (dilute nitric acid solution) or chromated. Chromating is done to improve the corrosion-resistant properties of the zinc plate or to enhance the adhesion of paint to the zinc plated parts. Table 6 illustrates the different plating operations performed for the different basis metals. Typical processing sequences for zinc plating-chromating steel parts in automatic-rack and automatic-barrel operations are shown in Appendix B, Table B-2, Lines 3 and 4, respectively.

The major source of zinc wastes results from the drag out of plating solution into the rinse waters. Other sources of zinc wastes are generated during the continuous or batch filtration of the bath, solution leakage from filters, pumps, and pipes, and floor spills. Zinc plating baths are rarely dumped.

Copper Plating(1-4)

Copper coatings are extensively used as undercoatings in multiple-plate coating systems. For example, the plating of zinc and steel parts with copper before nickel and chromium plates is common practice in the industry. Copper plating is also employed in electroforming and in the production of heavy coatings on wire for electrical applications. For some applications, bright electroplated copper, protected against tarnishing by an overcoat of clear laquer is used as a decorative finish. Copper plating is also widely employed in the production of printed circuit boards.

Copper can be electrodeposited from numerous electrolytes; however, four main types (i.e., alkaline cyanide, alkaline pyrophosphate, acid sulfate, and acid fluoborate) account for most of the commercial plating. Typical compositions and operating conditions for the copper cyanide baths are shown in Table 19. Similar data for the acid sulfate and acid fluoborate baths are presented in Table 20.

Copper can be electroplated in still tanks, barrels, and in automatic equipment. Steel tanks, lined with rubber or plastic, are generally employed for copper plating from cyanide and acid copper electrolytes. External heating of cyanide baths is suggested using a steel heat exchanger (brass or bronze fittings should not be employed). Special grades of carbon or graphite pipe and tubing make efficient heat exchange or cooling coils for acid copper baths. Soluble copper anodes in a variety of shapes are generally employed in plating copper from the several baths, although insoluble anodes of steel or lead alloys are sometimes employed for special jobs or applications.

TABLE 10. TYPICAL COMPOSITIONS AND OPERATING CONDITIONS FOR CYANIDE COPPER PLATING BATHS(4)

Constituent or Condition	Plain Cyanide	Rochelle Cyanide	High Efficiency
	Composition, grams/liter		
Copper cyanide	15	26	75
Sodium cyanide	23	35	93
Sodium carbonate	15	30	-
Sodium hydroxide	-	4	30
Rochelle salt	-	45	-
Free sodium cyanide	6	6	11
	Operating Conditions		
Temperature, C	55	60	70
Cathode current density, amp/sq cm	0.022	0.043	0.065
Anode current density, amp/sq cm	0.008	0.016	0.027

TABLE 10. TYPICAL COMPOSITIONS AND OPERATING CONDITIONS FOR ACID COPPER PLATING BATHS(3)

Constituent or Condition	Copper Sulfate	Copper Fluoborate	
		Low Copper	High Copper
Composition, grams/liter			
Copper sulfate, $CuSO_4 \cdot 5H_2O$	195 to 250	-	-
Sulfuric acid, H_2SO_4	30 to 75	-	-
Copper fluoborate, $Cu(BF_4)_2$	-	60	120
Fluoboric acid, HBF_4	-	To pH	To pH
Operating Conditions			
Temperature, C	21 to 49	27-77	27-77
Current density, amp/sq cm	0.022 to 0.108	0.081 to 0.135	0.135 to 0.378
pH	-	0.8 to 1.7	<0.6

Typical pretreatment steps in applying copper coatings to steel or brass parts generally are hot cleaning, rinsing, acid dipping, and rinsing. A cyanide copper strike or nickel strike plate is usually applied before steel or zinc alloy parts are plated in an acid copper bath. A typical sequence of operations used to apply a triple Cu-Ni-Cr coating on steel or brass parts is shown in Appendix B, Table B-2, Line 1.

The primary source of copper plating chemicals in the waste results from the solution drag out into the rinse waters. A secondary source of wastes is from spills or leaks from filters, pumps, and piping fixtures, etc. Copper plating baths are rarely dumped.

Tin Plating(1-4)

Tin coatings are generally applied for their desirable characteristics such as its resistance to corrosion and tarnish, its nontoxic nature, its solderability, and its softness and ductility. The largest single use of electrodeposited tin coatings is in the tin plate industry. Electroplated tin is also extensively employed as a coating on refrigerator parts, dairy and other food handling equipment, washing machine parts, kitchen ware, automotive pistons and piston rings, radio and electronic components, electrical lugs and connectors, and copper wire.

Tin is deposited from both alkaline and acid solutions. Representative compositions and operating conditions for stannate tin plating baths are given in Table 21. Similar data for acid tin plating baths are presented in Table 22.

Typical pretreatment steps prior to stannate tin plating are: cleaning, rinsing, acid dipping, rinsing, cyanide or caustic dipping, and rinsing. For acid tin plating, the cyanide or caustic dipping step is omitted.

Tin can be electroplated in still tanks, barrels, and in automatic equipment. Mild steel tanks, unlined and equipped with steel heating coils are suitable for stannate tin plating. Rubber-lined or synthetic-lined tanks or equipment are required for the acid tin baths. Soluble tin and insoluble steel anodes can be used with the stannate baths, while soluble tin anodes are generally employed in the acid baths.

The major source of tin waste is the drag out from the plating baths into the rinse waters. Settled sludges from the stannate bath, leakage from filtration equipment and piping in the acid baths, and accidental spills are secondary sources of wastes from the tin plating baths. The plating baths are rarely dumped.

Iron Plating(1-4)

Iron is used for building up heavy deposits on worn parts, for printing plates, for electroforming and, occasionally as a substitute for

TABLE 21. REPRESENTATIVE COMPOSITIONS AND OPERATING CONDITIONS FOR STANNATE TIN PLATING BATHS(2-4)

Constituent or Condition	Bath 1	Bath 2	Bath 3	Bath 4
	Composition, grams/liter			
Potassium stannate	100	210	420	--
Potassium hydroxide	15	22	22	--
Sodium stannate	--	--	--	100
Sodium hydroxide	--	--	--	10
	Operating Conditions			
Temperature, C	65-90	70-90	70-90	60-85
Current density, amp/sq cm	0.03 to 0.11	0.17 max	0.43 max	0.005 to 0.032

TABLE 22. COMPOSITIONS AND OPERATING CONDITIONS FOR ACID TIN PLATING BATHS(2-4)

Sulfate Bath		Fluoborate Bath	
	Composition, grams/liter		
Stannous sulfate	53	Stannous fluoborate	200
Sulfuric acid	98	Fluoboric acid (free)	80
Cresol sulfonic acid	98	Boric acid (free)	25
B-naphthol	1.0	B-napthol	1.0
Gelatin	2.0	Gelatin	6.0
	Operating Conditions		
Temperature, C	21 to 38 C	Temperature, C	21 to 43
Current density, amp/sq cm	0.011 to 0.432	Current density, amp/sq cm	0.08 to 0.14

nickel. Iron plating solutions are slightly acidic, containing sulfates, chlorites, fluoborates, or sulfamates. The basis metal is prepared for iron plating by cleaning, rinsing, acid dipping, and rinsing. The parts are rinsed and dried following plating. Soluble ARMCO iron anodes are used for the process.

A most useful bath is the one containing 127 g/l (17 oz/gal) $FeCl_2$ and 111 g/l (15 oz/gal) $CaCl_2$. The sulfate/chloride bath contains up to 20 g/l (3 oz/gal) of ammonium chloride in addition to 250 g/l (33 oz/gal) ferrous sulfate and 30 g/l (4 oz/gal) of ferrous chloride. The fluoborate bath is sold as a concentrate and upon dilution with water contains typically 225 g/l (30 oz/gal) ferrous fluoborate, 10 g/l (1.3 oz/gal) sodium chloride and 22.5 g/l (3 oz/gal) of boric acid.

Drag-in to rinse water after plating is the major source of waste; floor spills and leakage from filter systems are a secondary source. Fluoborate ions will have to be treated where such a bath is used. Small amounts of ferric ion in the sulfate and chloride baths precipitate as hydroxide or oxides and are removed by filtration.

Gold Plating

Gold and gold-alloy coatings are applied for decorative purposes, as on jewelry, and for other applications requiring oxidation and tarnish resistance. Gold plating is also used in applications of electrical contacts and to achieve high solderability.

The majority of gold plating operations are performed using cyanide solutions. Typical compositions and operating conditions for gold cyanide plating baths are listed in Table 23. Additions can be made to the various plating baths to produce various gold-alloy plates; for example, 7 to 15 mg/l of antimony tartrate added to the cyanide gold-plating bath produces a gold-antimony alloy deposit, indium cyanide additions produces a gold-indium deposit, and gold-gallium deposits have been produced by the addition of gallium salts. Some gold plating baths contain no free cyanide and may contain gold and potassium phosphate or gold and ammonium citrate.

Gold coatings are predominantly produced from baths in which the gold is supplied in the form of salts such as $KAu(CN)_2$ or $NaAu(CN)_2$. Anodes used may be made of stainless steel, carbon, platinum-clad tantalum, and platinum-plated titanium. (Gold anodes are used to supply gold to the solution, but are used less often than are insoluble anodes in conjunction with gold solutions.)

Gold solutions and the drag out to rinse tanks are largely recovered with the gold extracted either in the plating plant or by a separate reclaiming service. The gold may be recovered by evaporation, precipitation by zinc, electrolysis, or by ion-exchange methods.

TABLE 23. RANGES OF COMPOSITIONS AND OPERATING CONDITIONS FOR CYANIDE GOLD-PLATING SOLUTIONS

Constituent or Parameter	Units	Range of Variables
Gold	g/liter	1-8
Free KCN	g/liter	0.1-30
K_2HPO_4	g/liter	15-30
K_2CO_3	g/liter	0-30
pH	pH	10-11.5
Temperature	C	55-70
Cathode Current Density	mA/cm^2	1-10

Silver Plating$^{(1-4)}$

Silver is used for decorative, protective, and engineering coatings. Thin deposits of 2.5 µm (0.0001 inch) are applied over jewelry and such. Coatings from 25 to 50 µm thickness (0.001 to 0.002 inch) are applied to tableware and holloware. Thicker deposits of up to 1500 µm (0.060 inch) are applied for bearings and electroforms. The bath concentrations normally increase as the desired coating thickness is increased.

The silver in plating baths is present as a cyanide complex together with free cyanide and carbonate. Silver concentrations vary from 25 to 75 g/l (3.5 to 10 troy oz/gal). Additives are used for grain refinement and brightening.

Strike solutions are generally employed in the basis metal preparation. After cleaning, rinsing, and dipping in cyanide or acid solution, and rinsing, the basis metal is activated by anodic or cathodic treatments. For example, stainless steels may be anodically treated in sulfuric acids or cathodically activated by striking in a Wood's nickel bath which is composed of 250 g/l (3.2 oz/gal) nickel chloride and 120 ml/l (16 oz/gal) hydrochloric acid. Silver strike solutions, with a low metal content (of about 6 g/l (0.2 troy oz/gal) of silver and high cyanide content of 75 to 90 g/l (10 to 12 oz/gal), are used for nonferrous basis metals. Ferrous materials are prepared first by striking in copper cyanide solutions of similar composition prior to silver striking. Consequently, the number of process steps is greater for silver plating than most other plating operations.

Steel tanks, stoneware and lined tanks are normally employed for silver plating, and the operations can be carried out manually or automatically. Both racks and barrels are used for silver plating. Soluble anodes are used for normal silver plating, whereas strike solutions would use insoluble anodes.

The metal is generally recovered for refining and extra precautions are taken to avoid spills and leaks, because of the high cost of the metal. Dumping of solutions is not practiced. However, the cyanide portion of the waste must be treated by destruction.

Anodizing

Anodizing is an electrolytic oxidation process by which the surface of the metal is converted to an insoluble oxide having desirable chemical and physical properties. Considerable aluminum is treated, some magnesium and limited amounts of zinc and titanium. Aluminum is anodized in 12 to 15 percent sulfuric acid to produce an oxide coating for corrosion protection and as a basis for decorative color finishes with dyes, or a hard coat for extra wear resistance. A 5-10 percent chromic acid bath is used where solution may become entrapped without current in recesses. In such a case sulfuric acid would attack the aluminum. Aluminum may also be anodized in oxalic acid or boric acid. The characteristics of anodic coatings on magnesium can be varied from thin coatings to give good paint adhesion to heavy coatings for abrasion and corrosion resistance in solutions containing fluorides, phosphates and dichromates. Some zinc parts are anodized to improve corrosion resistance.

Pretreatment operations for anodizing involve one or more of the following steps: Alkaline cleaning, caustic etching, deoxidizing, desmutting and bright dipping depending on the alloy used and the desired finish. Posttreatment includes color cying and sealing with hot water or nickel acetate solution.

Steel, rubber-lined, plastic, and lead-lined tanks are used for anodizing. The latter may be used as the cathode in sulfuric acid anodizing. Lead cathodes must be used elsewhere except for chromic acid anodizing where a steel tank could serve as a cathode. Wastes are generated by drag in of process solutions into the rinse waters. Solutions are occasionally dumped. Spills are a secondary source of waste from anodizing solutions.

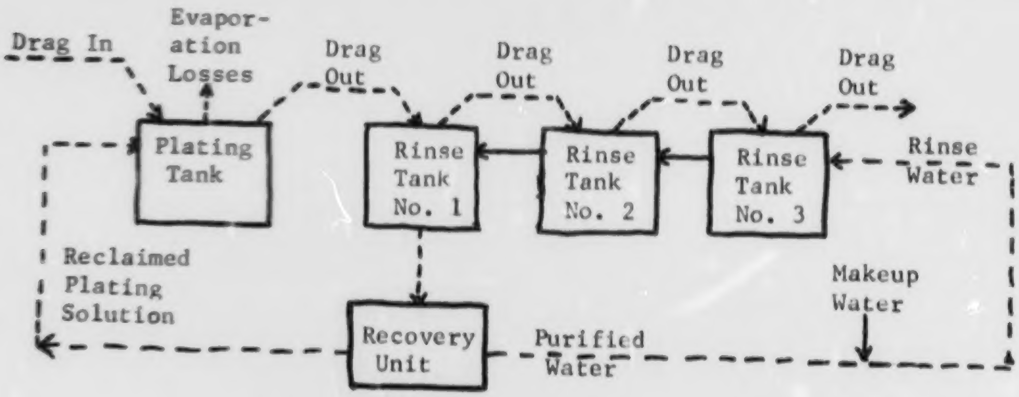
Materials Reclamation

In conventional electroplating operations, a sludge is produced from the dump streams and the treatment of rinse waters by the so-called "destruct" systems in plants from a wastewater treatment system. Examples of these systems are the oxidation of cyanide wastewater with sodium hypochlorite, NaClO, and the reduction of hexavalent chromium to trivalent chromium with waste pickle liquor before neutralization and precipitation of both with either sodium hydroxide or a lime slurry. The resulting sludge is separated and sometimes dewatered. The common method for handling this sludge is disposal in landfill sites.

Several recent developments have forced changes in this procedure. Among these are new regulations on the discharge of toxic materials, the small number of certified landfill sites, and the rising costs of plating metals and chemicals. The alternative methods are aimed at reclaiming the dissolved plating metals in the wastewater during the plating operation in closed or partially closed systems, thus circumventing sludge formation altogether. However, in the present state of the art there is still a need for a small destruct system to neutralize spills, fumes, dumped plating baths, unrecovered plating acid drag out, etc. Recovery units used to recover chemicals from plating bath rinse water are fairly widely used; however, they have not been installed on cleaner or acid dip lines because the cost of chemicals is not sufficient to make recovery worthwhile. Also, buildup of contaminants such as oil and grease makes the use of such closed systems difficult.

Treatment of the effluent to recover plating chemicals falls into two categories: (1) treatment of the entire volume of effluent by various recovery methods, and (2) partial recovery. The simple schematics shown in Figure 2 illustrates the difference. The total recovery unit illustrated

A. Total Reclamation



B. Partial Reclamation

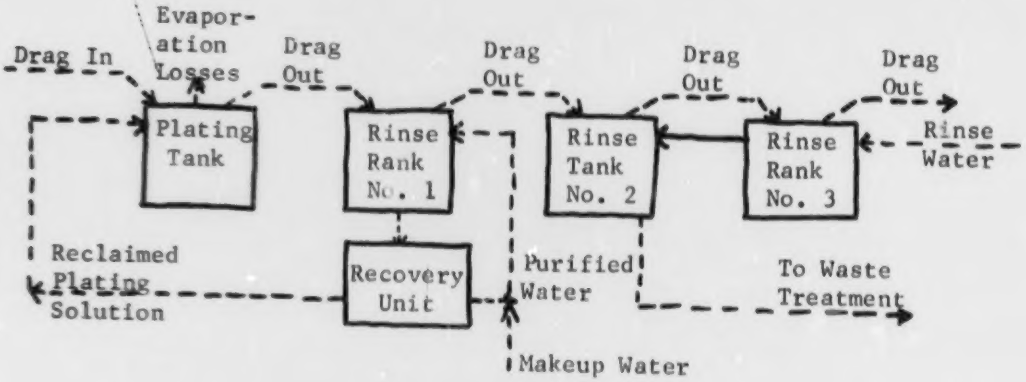


FIGURE 2. TOTAL AND PARTIAL RECLAMATION OF PLATING CHEMICALS LOST THROUGH DRAG OUT(5)

in Figure 2A handles three times as much water as the partial recovery unit, Figure 2B, and has a capital cost of about 2.5 times that of Figure 2B. With careful water conservation practices, 90 percent recovery of the chromium and nickel plating chemicals can be achieved with the partial recovery unit shown in 2B. Where the main purpose is to recover plating chemicals and return them to the process baths, partial recovery units such as 2B are used. Further improvement in the recovery of plating chemicals (up to 99 percent) is possible if rinse tank No. 2 is added to the recovery loop shown in 2B. It is not often economically feasible (or even physically possible) to treat the entire volume of effluent. Usually selective and integrated treatment is combined with conventional treatment.

Ion-Exchange Recovery Units(6,7)

One method for recovering metals from the plating bath is by ion exchange. In using this technique, the wastewater passes through an ion-exchange system to regenerate the captured plating solution and selectively capture the contaminants that build up in the plating bath. The treated water is recovered and reused as rinse water. Figure 3 is a schematic of an ion-exchange system used for the recovery of chromic acid. Note that the principle is to return as much drag out as possible to the plating baths through countercurrent rinse baths. Rinse water from the last rinse stage is then recirculated over cationic and anionic filters arranged in series. The eluate from the anionic exchanger contains sodium chromate, Na_2CrO_4. It is returned to the chromium bath through a cationic exchanger saturated with hydrated hydrogen ions.

Ion exchange is an economically attractive method of concentrating plating chemicals. It also permits the removal of metallic impurities from rinse water and its reuse. It has not worked well on cyanide rinse water; however, a 3-bed system consisting of a strongly acidic, weakly basic, and strongly basic ion exchanger has been used in Europe for removing cyanides. Small evaporative recovery units may be needed to augment ion-exchange recovery; in some cases small evaporators may be needed to raise the concentration of the output from the ion-exchange unit.

Evaporative Recovery Units(5-7)

Evaporation is a firmly established procedure for recovering plating chemicals and rinse water from plating waste effluents. Over 100 evaporative units (i.e., single-, double-, multiple-effect, and vapor-recompression evaporator units) have been installed in the U.S. These units are used in partial recovery loops such as that illustrated in Figure 2B, and also in combination with other recovery methods such as ion exchange and reverse osmosis. Vapor-recompression evaporators are used only where steam evaporators are not available, and thus the high cost of the expensive and complex compressor can be economically justified.

Single-effect evaporators are less efficient than double effect or vapor-recompression units; however, they require less initial capital,

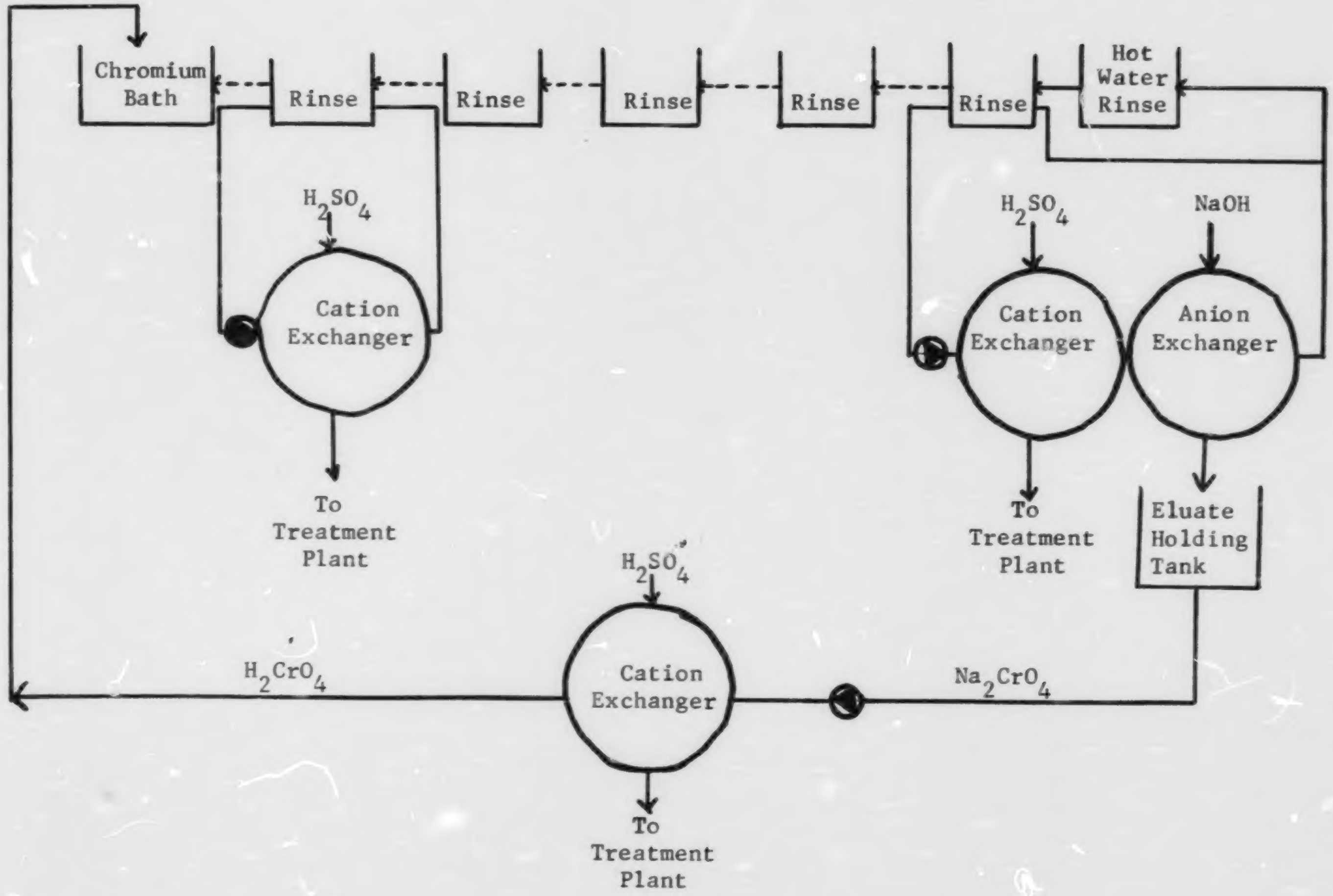


FIGURE 3. CHROMIC ACID RECOVERY BY ION EXCHANGE(6.7)

and are easier to operate with inexperienced personnel. There are a number of single-effect evaporator units available. They are as follows: (1) evaporation based on the cooling tower principle, (2) submerged-tube evaporation, (3) flash evaporation, and (4) "climbing film" evaporation. The latter, a new concept introduced by the Corning Glass Company, is illustrated in Figure 4. The illustration shows an arrangement for partial recovery such as that shown in Figure 2B. Only minor changes would be required to achieve total recovery such as that diagrammed in Figure 2A.

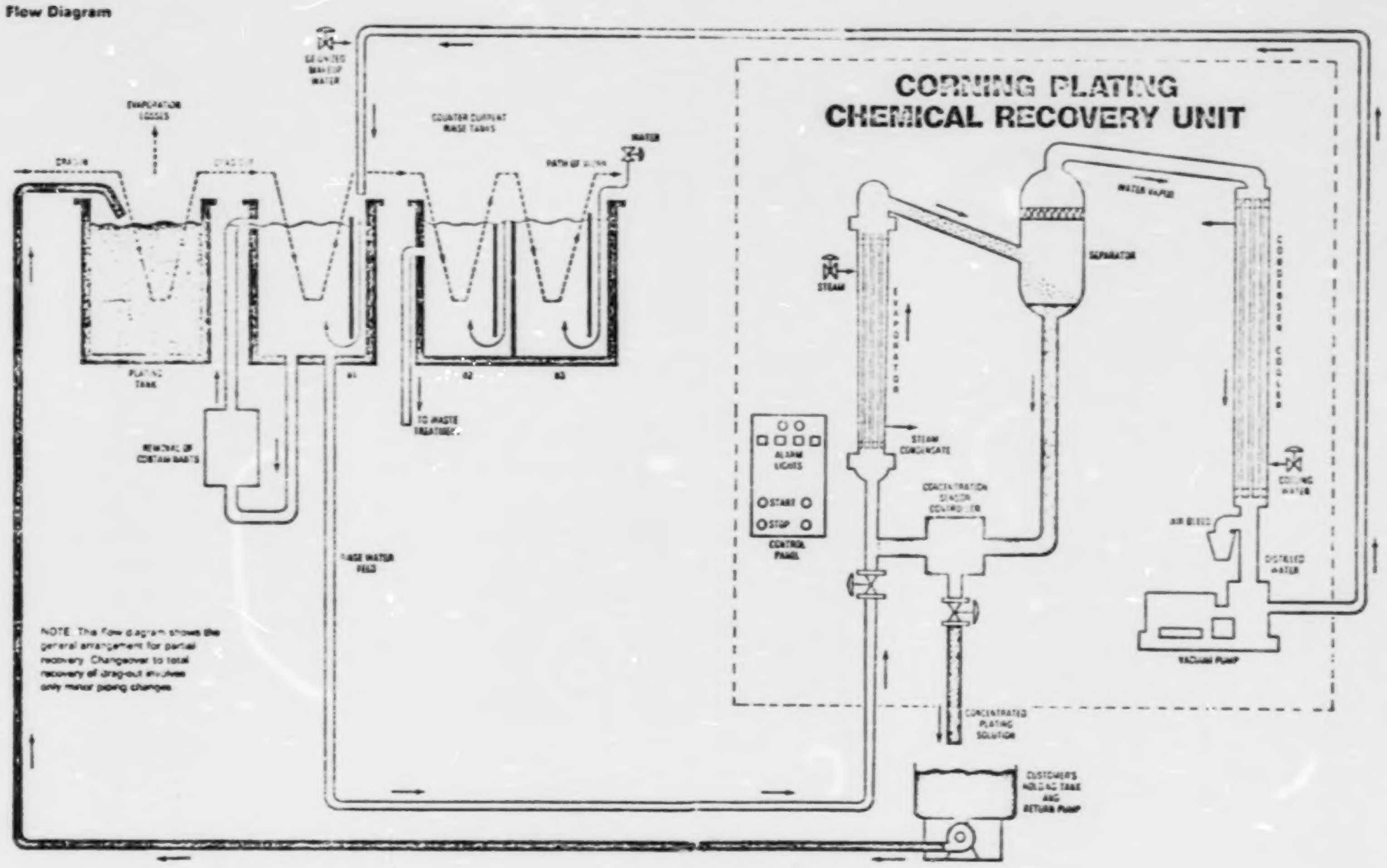
The recovery unit shown at the right in Figure 4 consists of a glass shell and a tube heat exchanger mounted vertically. The solution is fed through the bottom of this evaporative unit. Boiling of the solution causes the liquid to surge and this produces a "climbing film" effect which improves the heat transfer. Vapor and liquid overflow from the top of the tube are separated in the cyclone. Recycled rinse water containing less than 0.05 ppm of chromic acid can be produced from chromium plating rinse water using this method.

In concentrating the rinse water by evaporation to recover chemicals in such operations as chromium and nickel plating, relatively high plating bath temperatures aid recovery. Nickel baths operate at around 60 C (140 F). Accordingly, considerable evaporation at this temperature permits the recovery of most of the drag out by countercurrent rinsing alone. However, to reduce the number of rinsing stages and provide for a good rinse efficiency, evaporators (or alternative recovery mechanisms) are used. Chromium baths operate at lower temperatures than nickel baths, 40-50 C (104-122 F), thus it is more difficult to recycle chemicals by countercurrent baths alone, and, therefore, evaporators (or alternative recovery mechanisms) are necessary.

Closed-loop evaporative recovery systems require close control of the bath for good operation. For example, nickel baths are treated with activated carbon to prevent contamination by organic substances. Metallic impurities such as iron, copper, and zinc are precipitated selectively by electrolysis.

In addition to its use in nickel and chromium plating, evaporative recovery units are being used on gold plating baths. Systems for zinc, copper, brass, and cadmium cyanide baths, and for lead-tin-copper fluoborate baths have also been installed.

Zinc cyanide baths operate most efficiently at 25-30 C (67-86 F) and require cooling to maintain this temperature. Accordingly, cooling towers have been used to cool the baths and concentrate them at the same time. Carbon dioxide is absorbed in the process which in turn leads to the rapid formation of zinc carbonate. This must be removed either by freezing or precipitation with calcium in a separate treatment. This and problems arising from small amounts of impurities in the zinc cyanide bath make this method of recovery marginal.



NOTE: This flow diagram shows the general arrangement for partial recovery. Changeover to total recovery of drag-out involves only minor piping changes.

FIGURE 4. CORNING CLIMBING FILM EVAPORATION RECOVERY UNIT FOR PLATING CHEMICALS(5)

Reverse Osmosis Recovery Units(6,7)

Concentration of the rinse waters from nickel plating baths is performed in a number of installations utilizing reverse osmosis units. Commercial reverse osmosis units for zinc and copper acid plating rinse water have also been installed.

In reverse osmosis, a pressure differential across a membrane forces the water through the membrane, leaving behind most of the dissolved salts. Using this method, salts in the rinse water from nickel and copper sulfate plating baths can be concentrated to solutions containing up to 15 percent salts, by weight.

Several membrane support systems are in commercial use; these include plate and frame, tubular, spiral wound, and hollow fine fiber designs. The cellulose acid membrane used in most of the development work to date has a limit on the pH of solutions that can be handled. The pH range of 3 to 8 precludes treating either strongly acid or alkaline solutions. Spiral wound and hollow fiber polyamide membranes have been tried on copper, zinc, and cadmium cyanide baths on an experimental basis. Pilot plant trials have also been run on copper cyanide rinse water; however, there have been problems with this system with fouling of the membrane. One of the disadvantages of reverse osmosis recovery units is the tendency toward fouling of the membrane by slightly soluble components in solution and by suspended solids in feeds (feeds must be amenable to solids separation before treatment by reverse osmosis).

Other Recovery Methods; Current State of the Art

There are a number of other recovery methods which are being tried out but have not yet reached commercial scale. These include freezing, electrodialysis, ion-flotation techniques, electrolytic stripping, carbon absorption, and liquid-liquid extraction. These are scattered operations using chemical precipitation and crystallization from solution. Commercial electrolytic recovery of tin and silver from plating bath rinses is also being done.

It is evident from the discussions on materials reclamation that there are still many types of metal plating processes which are not yet amenable to problem-free, closed-loop reclamation. This is particularly true in the case of zinc, copper, and cadmium cyanide plating baths. Continuous closed-loop reclamation of plating chemicals from nickel and chromium plating baths has proven to be commercially feasible; however, there are still problems with these recovery systems. Closed-loop systems are subject to impurity buildup which requires bleedoff from time to time. While the main process loops may be closed, secondary purification loops are much more difficult. Thus, nickel impurities can be removed from chromium plating baths by ion exchange and returned to the nickel bath in a closed-loop system, but sodium sulfate and sodium chloride are excess which cannot be completely returned to the process. There is also the problem of sludge from acid dip and cleaner line rinses for which recycling usually is not economical. Research is continuing in this area of reclamation; the Metal Finishers Foundation has put priority on the concentration and recycling of cyanide compounds in plating baths.

WASTE STREAM GENERATION

In performing the study of the electroplating and metal finishing industry, four waste types were identified as being destined for land disposal. These are as follows:

Water-pollution control sludges
Process wastes
Degreaser sludges
Salt precipitates from electroless nickel bath regeneration.

Water-pollution control sludges have been identified as a class because they constitute the largest single waste category destined for land disposal. Included in this category are rinse waters from each plating step which contain potentially hazardous chemicals dragged out from concentrated plating solutions. Also included are process solutions--such as alkaline cleaners, acid dips and pickles, and conversion coating solutions--some of which are dumped at regular intervals. Water pollution control, when practiced at an electroplating and metal finishing facility, will precipitate the dissolved potentially hazardous facility materials, thus generating a sludge for land disposal.

Process wastes include grinding, polishing, and buffing dusts, filter aids, anode sludges and anode bags, plating racks, and rack materials. Most of these materials bear occluded or absorbed process chemicals and are generally disposed of by landfill means, either separately disposed or mixed with the normal refuse.

Degreaser sludges are in most cases chlorinated hydrocarbons which are used to remove greases and oils from mechanically finished parts. These sludges then contain dissolved greases and oils, buffing compounds, abrasives, cloths, and metals. They may be discarded through the routes of direct disposal to the land or may be routed to a reclamation operation (e.g., distillation).

Salt precipitates from electroless nickel plating operations are produced during the regeneration of the bath composed of calcium orthophosphite and calcium sulfate. The plating bath chemicals contained in the precipitate may be returned to the bath by washing the filtrate. This particular type of waste may not always be present since electroless nickel plating operations are not as common as electroplating operations or small volume solutions are not regenerated.

A simplified representation of the relationships between the sources and the types of wastes is shown in Figure 5. Details and variations from the concept are discussed in the following paragraphs.

Water Pollution Control Sludges

The source of these sludges is the process solutions drag out from the workpieces as they are moved from tank to tank in any plating operation. The concentrated process solutions carried out as drag out are rinsed in continuously flowing water at a rate which ranges from 1 to 10 gallons per minute. The water flow rate depends on the number of rinses and whether or not they are connected to each other in a countercurrent or select mode.

The rinse waters contain alkalies, acids with dissolved metals, and possibly cyanides from the preplating steps. The metal or metals being plated onto the workpieces appear as dissolved salts in the rinse waters following metal deposition steps. Also present are conductivity salts and additives which were introduced to enhance electrodeposition or the properties of the deposits. Some plating processes incorporate a post-plating step intended to alter the metal surface by conversion or filming to improve on the corrosion properties of the deposits. Drag outs from these solutions also contain metals and chemicals. The rinse waters are then collected throughout the plant in three distinct streams. One stream carries all cyanide-bearing wastes, another all chromium-bearing wastes, and a third stream contains all alkalies and acids and metal salt solutions other than chromium and those metals which are chemically bound to cyanide. The hazardous chemicals are then destroyed or reduced by passing the streams through a water pollution control system, metals are precipitated and separated, and the effluent is discharged to a stream or sewer.

Plating solutions contain valuable metals in concentrations as high as 200 g/l (27 oz/gal), as well as chemical salts and additives. For these reasons, plating solutions are maintained by purification and filtering and are rarely ever disposed of. In contrast, pre- and postplating solutions are dumped at regular production intervals as spent baths, and metered into the water pollution control equipment for treatment along with the rinse waters. Such solutions are alkaline soak and electrolytic cleaners, acid and cyanide dips, pickles, descaling baths, chemical and electrochemical polishing baths, oxidizing, phosphating, coloring, and conversion coating solutions.

Spills and leaks from process tanks may also occasionally occur. With proper plant equipment maintenance and good housekeeping such hazardous waste generation can be kept to a minimum. When it does occur, the wastewater is handled by the water pollution control equipment adding additional but relatively minute quantities of sludges for disposal.

Water Pollution Control Technology

The chemical treatment of wastewater from electroplating and metal finishing operations involves simple chemical reactions carried out on a batch or continuous type basis. This type of operation should provide sufficient holding time to complete these reactions, continuous monitoring of oxidation-reduction potentials and pH, and controls for regulating reagent additions. The amount of metals precipitated depends on the insolubility of their hydroxides. When solubilizing complexing agents are present, precipitation is not as complete, so additional or different chemical steps may be required. For example, cyanide ions must be destroyed, not only because they are toxic but also because they prevent the effective precipitation of metals as hydroxides. Similarly, chelating agents, such as EDTA (ethylene-diamine-tetraacetic acid), when used in some process solutions, make complete metal hydroxide precipitation more difficult. But since these compounds are used only in very small quantities at concentrations of a few mg/l, the amount of water pollution control sludge is reduced by only an indescribably small fraction.

The first reaction to be considered is the destruction of cyanide to nitrogen and carbon dioxide using chlorine or hypochlorides. Another process to destroy cyanide is to use ferrous sulfate which forms ferrocyanide and does produce a solid waste. This process is used very infrequently and then only for the destruction of very concentrated cyanide wastes if for no other than economic considerations.

Other anions found commonly in electroplating and metal finishing operations with the exception of fluorides, fluoborates, and phosphates cannot be removed by precipitation and therefore escape in the effluent and do not produce a solid waste. Fluorides and fluoborates can be used with practically all metals for the electrodeposition and at times for etching of certain basis metals. The most common use is in the electrodeposition of lead and tin coatings and their alloys for bearing materials and solder applications. Fluoborates hydrolize to HF and BF_3 in dilute solutions and the fluoride can be precipitated with lime for disposal as a sludge. Fluoride removal is not as complete as desired, with more than 10 ppm escaping with the effluent stream. Phosphates are present in alkaline cleaning solutions; however, there is a trend to reduce their concentration or eliminate their use because they are difficult to remove from plant effluents by precipitation as calcium diphosphate ($CaHPO_4 \cdot 2H_2O$), which has a solubility of 0.2 g/l in cold water. The sodium diphosphate which would result from the use of caustic is much more soluble. Heavy concentrations of phosphates are found in rinses following electropolishing and chemical polishing operations where concentrated phosphoric acid is employed. In plants which process aluminum, aluminum phosphate is precipitated ($AlPO_4$) when these two ions are present in the same neutral solution. Thirty to thirty-five percent of the concentrated phosphoric acid solutions are not expected to produce solid waste since they can be used as a raw material for the manufacture of fertilizer. Zinc or iron phosphates are used in the processing of steel as a corrosion-protective undercoating and/or as a bonding agent in electropainting processes. Their concentrations in this application are about one-tenth of those used in electroplating operations, and the phosphates as well as the metals are removed from solution by dry lime precipitation for disposal with the water pollution control wastes.

The next chemical reaction to be considered is the reduction of hexavalent chromium to trivalent chromium using sulfite-containing compounds or ferrous sulfate.

In acid solutions these reactions are as follows:

$$2H_2CrO_4 + 3H_2SO_3 \rightleftharpoons Cr_2(SO_4)_3 + 5H_2O$$

or

$$2CrO_3 + 6FeSO_4 + 6H_2SO_4 \rightleftharpoons 3Fe_2(SO_4)_3 + Cr_2(SO_4)_3$$

and

$$Cr_2(SO_4)_3 + 6NaOH \rightleftharpoons 2Cr(OH)_3 + 3Na_2SO_4.$$

In using ferrous sulfate as a reducing agent, approximately twice the volume of sludge is produced since three moles of ferric sulfate must also be precipitated and removed as the hydroxide.

In alkaline solutions hexavalent chromium can be reduced and precipitated with hydrazine.

$$4H_2CrO_4 + 3N_2H_4 \rightleftharpoons 4Cr(OH)_3 + 3N + 4H_2O.$$

Chromium wastes are generated from chromium plating solutions, chromates and dichromates from bright dipping, electropolishing, and the conversion coatings on zinc and cadmium. Large installations for bright chromium plating, where the plating time is only from 5 to 15 minutes contribute large quantities of chromium to the waste stream, whereas fewer installations for hard chromium plating with a plating time of several hours contribute much less to the waste. Conversion coating solutions, although having a much smaller bath concentration of chromium (~15 g/l), are periodically dumped and consequently contribute significant quantities of chromium to the waste stream.

Other finishing operations performed in electroplating and metal finishing facilities will also generate a waste. Chemical milling of aluminum is one of these operations and is carried out in an alkaline solution. The resulting wastes can be used for phosphate precipitation where the phosphates are part of the plant operations, which is generally the case in the metal finishing of aluminum. Milling of other metals is carried out in acid solutions and hydroxide sludges are formed by neutralization.

Neutralization and chemical precipitation are also used to remove heavy metals from the rinses of etching operations. The etching solutions themselves are generated by electrolyzing in a closed-loop system. Where the etchants contain chromates, acetates, or ammonia, as is the case for some printed-circuit manufacturing, and as a pretreatment for plating on polystyrene, polyethylene, polyvinylchloride, polycarbonate, polysulfone, polypropylene, and ABS, they are shipped to recovery plants. With the exception of the last two materials, all require solvent treatment to make the surface hydrophilic. The contaminated solvents are reclaimed by distillation after being shipped in drums to a reclaimer or the supplier and are, therefore, not destined for land disposal by the electroplating industry.

The plating of plastics is also performed and requires some additional process steps to those commonly employed for plating on metallic surfaces. Some of these steps are: (1) sensitizing the plastic, which involves the use of stannous chloride solution; (2) nucleation, which deposits a film of palladium metal; and (3) electroless plating. As an alternative to steps (1) and (2), palladium-chloride may be applied directly onto the plastic and then reduced to the metallic form by the use of formaldehyde, hypophosphite, hydrazine, or borane compounds. Of all the process steps, only the use of stannous chloride, when precipitated as the hydroxide in chemical waste treatment practices, adds to the sludge. Spent palladium solutions are returned to the supplier for recovery, while the palladium concentration is in the rinse on the order of ppb and is lost with the effluent.

The electroless plating solutions, which are also used to produce deposits on metallic surfaces, contain either nickel or copper. Nickel and copper wastes from both rinse waters and spent plating solutions are treated at pH 13 with caustic soda to destroy the complex and precipitate the metal hydroxides. Copper may also be precipitated as a metallic sludge by heating to ~60 C (150-160 F) for more than 4 hours. The resulting metal or metal hydroxide wastes go to land disposal, although it is not uncommon for the plater to return spent solutions to a supplier or scavenger.

The choice of the treatment chemical for metal hydroxide precipitation is between slurried lime, $Ca(OH)_2$, or caustic soda, NaOH, purchased dry or in liquid form. The stoichiometric quantities of hydroxide sludge produced per kg of metal are as follows:

$Al(OH)_3$	2.89	$Fe(OH)_2$	1.91
$Cd(OH)_2$	1.3	$Ni(OH)_2$	1.52
$Cr(OH)_3$	1.98	$Zn(OH)_2$	1.52
$Cu(OH)_2$	1.54		

Insoluble calcium carbonate is formed with the use of lime thus adding to the sludge volume; the remaining calcium or all of the sodium part of the reagents appears in the plant water effluent. Precipitation with lime is generally preferred since it produces a sludge wherein the gelatinous hydroxide colloids are less difficult to settle and easier to separate than with caustic. Reaction rates and efficiency are affected by the presence of other cations (Mg) or anions (CO_3), the pH of the solution, the time allowed before separating the solids, the precipitation agent (lime or caustic) used, and the degree of agitation. Reagent chemicals are added in excess from 5 to 10 percent.

Coagulant aids are usually required for sedimentation and separation. Iron salts as well as alum may serve this purpose; however, this will increase the quantity of sludge generated as the hydroxide. Polyelectrolytes are most commonly used in concentrations of 1 to 40 mg/l (0.01 to 0.03 lb/1,000 gal). For an average-size job shop with a water use rate of 230,000 l/day (60,000 gal/day), as much as 9.2 kg/day (20 lb/day) of flocculant is added. Solids adhering to the workpieces are removed during the alkaline or acid cleaning steps prior to electroplating are added to the total solid wastes for disposal. Alkaline wastes, such as soaps and detergents from burnishing or tumbling operations, are simply neutralized. Where ion-exchange systems are used for purifying tap or process water, any solutions used to regenerate these systems are also passed through the treatment plant.

Toxic fumes are also generated in many plating operations. Electrolytic cleaning solutions, cyanide, and chromium plating solutions all work at elevated temperatures and at current efficiencies ranging from 12 percent to less than 100 percent. That portion of the current which is not used for metal deposition or anode dissolution produces H_2 or O_2, respectively. The escaping gases carry with them various amounts of solution in the form of a mist which must be exhausted. Similar conditions exist for pickling, descaling, bright dipping, and chemical or electrochemical polishing. Dispersion of such fumes into the atmosphere is generally not permitted so that fume scrubbers or other cleaning devices may be required. Wet scrubbers or spray chambers are most often used. Depending on the waste treatment effort exercised by a plant, the resulting liquid wastes may either be handled with the plating wastes in the treatment system or periodically collected from the scrubber and returned to a scavenger. When processed through the treatment system, the acids or alkali are simply neutralized; but cyanides, chromic acid, and solutions containing metal ions add to the solid waste load of the plant.

Quantities of Sludge. The quantity of sludge produced in an electroplating and metal finishing plant is not uniform for any given process because the drag out and spillage varies from plant to plant. The reasons are: (1) processes plating the same finishes on the same basis metal vary from plant to plant, depending on the state of the art practiced in each plant; (2) process lines may be hand operated, semi-automated, or automated; (3) variations in the size and shape of the parts causes variations in the volume of solution drag out; (4) tank sizes affect rack design; (5) rinsing practices differ from high water-flow single rinse tanks to save rinses, or mists which collect and return drag out chemicals to the plating baths; (6) deposit thickness directly affects the production rate, i.e., the thinner the coating applied the more drag out results for a given size installation; (7) simple housekeeping practices by maintaining all equipment and containing spills reduces the waste load; and (8) water conservation through control technology with the use of ion exchange, evaporative recovery, reverse osmosis, freezing, electrodialysis, electrolytic stripping, carbon adsprtion, ion flotation, and liquid-liquid extraction.

The control technology which may be utilized has specific applications. In all instances, it is applied to the plating solutions, but not to the cleaners or acid rinses. Ion exchange is used for in-process control of raw water, processing baths, and rinse waters. If the application is to produce deionized water or to remove impurities from the plating bath, more heavy metals are generated and have to be disposed of as a concentrate from the backwash operations or fed to the chemical treatment system. On the other hand, concentrates may be returned to the baths, eliminating the need for dispersing of a waste to the land. Examples would be the recovery of chromic acid or phosphoric acid.

Evaporative recovery systems greatly reduce the quantity of waste by returning large portions of the drag out chemicals to the baths and also recycling the rinse waters. These units are commercially applied to zinc, copper, cadmium, chromium, and nickel baths. Because continuous recycling increases the contaminant concentration in the baths, some of the concentrate is discharged and the system falls short of being able to achieve zero discharge and, consequently, zero sludge disposal.

Reverse osmosis employs a pressure differential across a membrane to separate the solution into a concentrate and a solution approaching the purity of the solvent. Units having a through-flow rate of less than 1200 l/hr (300 gal/hr) have been installed to recover plating bath chemicals and make closed-loop operations of the plating baths possible. The disposable waste would be worn and fouled membranes.

Electrolytic stripping has been used for the recovery of precious metals, copper and tin. In order to strip a solution by electrodeposition of its metal, it is necessary that the metallic ions in a dilute solution reach the cathode surface at a sufficient rate so that essentially all of the metal ions can be deposited in a reasonable time. This can be accomplished by pumping the solution between closely spaced electrodes, through beds of metal or metal-coated glass spheres, through expanded metal or porous carbon electrodes. If cyanide is present in these solutions, and is not oxidized at the anode, it must be destroyed subsequently by chemical means.

Freezing, electrodialysis, carbon adsorption, ion flotation, and liquid-liquid extraction have also been considered but are still in the development stage. Pilot plant installations will not affect the quantities of the pollution control sludge, either now or in the near-term future.

Solids Separation and Sludge Disposal

The first step in separating the precipitated metals and undissolved solids from the treated wastewater is settling through clarifiers or solid contactors. Settling is accomplished by a batch process in a stagnant tank; after a certain period of time (normally over 2 hours) and after the clear effluent has been drawn off the side or the top of the tank, the sludge may be emptied through the bottom. The continuous system uses a baffled tank allowing the stream to flow first to the bottom and then rise with a decreasing vertical velocity until the precipitates can settle in a practically stagnant fluid. Clarifier underflow or "sludge" contains typically 1 to 2 percent solids and is pumped to a pond, lagoon, or holding sump or further processed by dewatering. Flowthrough ponds, lagoons, or sumps discharge some more effluent to a stream or sewer system causing a thickening of the sludge to 4 to 6 percent solids. (Their holding capacity is no less than the sludge accumulated during a 30-day production.) This sludge is periodically removed by tank trucks to a disposal site. In other instances, seepage-type ponds are used where the effluent part of the sludge is allowed to percolate through the ground causing the sludge to thicken to where it possibly could contain as much as 12 percent solids. The dangers associated with lagooning are seepage of wastewater associated with the sludge into the aquifer or to adjacent streams. Percolating ponds are found with plants located in rural areas where there is sufficient land available. Plants in urban areas are forced to use holding sumps. Depending on the size of the plant and the space available the sumps may have to be emptied weekly, biweekly, monthly, or in rare cases, less frequently.

Centrifuges will also thicken sludges to a consistency of 8 to 12 percent solids. The effluent, however, contains suspended solids in excess of 20 mg/l and needs to be recirculated to the clarifier. Centrifuges require small amounts of floor space and less than half the land area that is required for lagoons or ponds. Lagooning may be avoided entirely by dewatering the sludge to a condition containing as much as about 50 percent solids. Rotary vacuum filters will concentrate a sludge containing 4 to 8 percent solids to 20 to 25 percent solids. The same solids content can be achieved with pressure filters but the filtrate contains less than 3 mg/l of suspended solids so that a return of the effluent to the clarifier is not needed. Semicontinuous tank filters may further increase the solids content to as high as 35 percent. Automated tank-type pressure filters and plate-and-frame presses produce the highest solids-content waste of about 50 percent. The choice of which dewatering device to use is one of economics, available space, or the limitations imposed on the ultimate disposal. The availability and area of privately owned land at or near a plant site is a factor in determining the disposal mode.

Sludge may also be solidified by addition of chemical fixing agents which insolubilize the metal hydroxides. The additions, of course, increase the volume of sludge destined for land disposal. The sludge is then similar in consistency to dried clay and reduces leaching to a fraction of a ppb of heavy metal.

Concentrated wastes rich in metals may be considered for recovery. This depends on the number and ratio of the constituents and the volume of the sludge. Large volumes of sludge in one location are economically favorable. For similar sludges from different plants a central processing station may accomplish such a task. However, very little effort, if any, is being expended at present to undertake such a task. As raw material prices increase and their availability decreases, the economics of recovery of sludges may become more favorable.

Ultimate sludge disposal, at the present, occurs at the following locations:

- Company on-site lagoons
- Municipal or private dumps
- Covered landfill
- Sewers.

Other possibilities are disposal at lagoons or landfill areas, incineration, recovery and reuse, or some disposal by deep-well injection, but none of these are practiced to any large extent.

Process Wastes

Process wastes can be separated into two distinct types (i.e., pre- and postplating preparation wastes and miscellaneous wastes. The first type of waste is generated in the electroplating and metal finishing process in the preparation of the basis material prior to metal deposition or the application of surface coatings. The appearance of the product is in many ways reflected by the way the underlying surface has been finished. Similarly, the protection given to a product against corrosion and wear, or the physical-mechanical properties of the deposit are, among other criteria, dependent on the preparation for plating. Depending on the size, shape, and number of parts, and finish desired, parts may be manually, automatically, or bulk finished. Depending on its surface condition, one or more operations may be necessary in preplating preparation. A postplating mechanical operation may also be desirable. All of these operations produce solid wastes which are composed of the materials being processed and the materials used to achieve a desired finish. These operations are: grinding, abrasive blasting, polishing, buffing, brushing, mass finishing by vibratory deburring, and barrel processes.

The second type of waste results from daily plant operations which are not precipitated metal hydroxide sludges or solids. They can be metallics from used anodes, plating racks, etc., or nonmetallics such as woven anode bags, coatings on plating racks, filter cakes, worn tank linings, etc.

Pre- and Postplating Preparation Process Wastes

Grinding. The most frequent application of grinding is associated with hard chromium plating. The uses of hard chromium are many, and it may be found in all types of industry for improving hardness, heat-, wear-, and corrosion-resistance, and for its low coefficient of friction. Grinding can be carried out before or after hard chromium plating. Worn parts, such as crankshafts, propeller shafts, cams, dies, molds, etc., can be salvaged by grinding back or cutting beyond the old surface coating. New parts can be processed in the same way, but it is common to manufacture these parts to within close tolerances and then plate the metal to the thickness desired. Sometimes the parts are overplated and then reground to finish dimensions. Included in this group are gauges, taps, molds for plastic and rubber, cutting tools, printing rolls, dies, gun barrels, and various shafts. The wastes that are generated are, of course, metallic chromium and the basis material to which the coating is applied, or an intermediate coating. Waste is normally disposed of along with the weekly refuse collection, or if in sufficient quantity, to a metal scrap dealer. Grinding carried out on bulk material is discussed later.

Abrasive Blasting. Materials are frequently finished by wet or dry abrasive blasting, for the removal of scale, rust, or other coatings; for roughening the surface or to improve or develop the surface for finish; for cold working (shot peening) to increase fatigue life; or to decrease susceptibility to stress corrosion or correct objectionable distortion. The amount of material removed depends on the type and quantity of abrasive used and the amount of mechanical or air pressure applied. Angular grit, steel shot, manufactured abrasives, such as aluminum oxide and silicon carbide, natural abrasives, slag products, and some glass beads are the most common recyclable materials, ranging in size from 50 to 500 mesh. Precleaning of the parts for the removal of soil is recommended to keep these materials clean for recycling. The natural abrasives include such items as pumice, silica, quartz, etc., and are used where metallic impurities introduced to the part to be finished cannot be tolerated. Sawdust, ground corncobs, crushed nut shells, glass beads, thermoplastic materials, etc., comprise the soft abrasives which are normally discarded with the weekly refuse. Dirt, soil, and scale are the only waste products from dry blasting operations where recycling equipment is attached. Loss of abrasives can occur by change of abrasive materials in the cabinet or through dust filters.

Polishing and Buffing. In metal finishing, after grinding comes the polishing operation which is done to achieve an intermediate surface that can be further refined by buffing prior to plating. The polishing operation may be carried out on metals or nonmetals; it removes some material from the surfaces. The purpose of buffing is to smooth and brighten the surface without much metal removal.

Polishing is carried out on hard-faced wheels varying in diameter, thickness, and material depending upon the part that is being processed and the finish and material removal rate that is desired. Wheels are constructed of woven cotton fabrics, canvas, felt, or leather discs glued or sewn together. Felt wheels are used where true surfaces are required or where a contoured shape is being finished. Leather wheels produce a finer finish, and wood wheels covered with leather are normally used for flat surfaces. Abrasives are generally applied to these wheels with synthetic adhesives or cements which have generally replaced the hide-glue formerly used. The ratio of abrasive to glue used in the facing of the wheels changes with grit size. Used wheels may be recoated after removal of lubricants from the facing or the facing itself may be replaced. The abrasives are fused-aluminum oxide, silicon carbide, and turkish emery. Tallow, grease, special bar lubricants, and spray lubricants are also used. Woven cloth belts are also used for polishing operations after having been treated in the same way as the wheels. Greaseless polishing can be accomplished with flexible polishing wheels using softer cloths. Burrs on castings or stampings may also be removed with the use of polishing wheels.

Buffing normally follows the polishing operation as the last step before plating. Depending on the desired finish of the product, the operations may vary. Satin finishes are obtained using fast cutting abrasives, mostly aluminum oxide and silicon carbide. Glue or adhesive binders are used to hold the abrasives, forming a greaseless compound buffing bar. Grease-base buffing bars are made of animal, vegetable, mineral fats, and waxes together with an adhesive. "Cut-down" buffing bars are composed of various materials, depending on the metal to be finished. Once-ground tripoli and aluminum oxide are the most widely used. An operation known as "cut-and-color" buffing is used in place of the cut-down operation to achieve a small amount of metal removal while at the same time giving some luster to the metal. Basically, the same constituents are used in different compositions to produce cut-and-color bars. Red iron oxide powder is frequently used for nonferrous metals. For producing a final finish having the best color and luster, very small amounts of very fine abrasives are used consisting of the materials listed above plus bars containing chromium oxide for finishing stainless steel and chromium.

Where semiautomatic or automatic machines are used, the buffing compound is not in a bar form but is applied in a liquid form from air pressure feed tanks or circulating drum pumping equipment. The newest development is a system of airless spray buffing. Liquid compounds are also available for manual buffing operations. The same abrasives that are used in buffing bars are used in liquid buffing; however, materials are oil solutions or water emulsions instead of grease, fat, waxes, and oils. Liquid buffing compounds produce better finish at a lower cost than maual operations with bar compounds, are required in smaller amounts, cause less wear on the buffing wheel, and cause less dirt to be packed onto the parts, which makes subsequent liquid cleaning easier. The different production techniques are summarized in Table 24.

The wastes produced from these operations contain three basic materials: (1) the metal removed by the abrasive media which will vary in quantity depending on the type and size of the abrasive, the contact time, the wheel diameter and speed, (2) the constituents of the specific compounds used, and (3) the materials used on the wheels and buffs. Items (1) through (3) are combined as one waste and collected from mechanical exhaust systems. This waste is disposed of in a landfill, although other means, such as incineration, are possible. Precious-metal wastes are more likely to be collected and incinerated, with the metals recovered from the ashes.

Wheels and buffs are consumed to about one-half of their diameter and then discarded as solid waste or returned to a supplier for recycling. In shops with small polishing and buffing operations, the former procedure is more likely to occur.

Where plastics are being processed (thermosetting, thermoplastic, molded or laminated, with or without fibrous filters), these materials are also part of the waste.

Mass Finishing. The improvement of surface finishes, the removal of burrs, edges and scales, and the forming of radii is specially obtained by tumbling or vibratory finishing of several parts at one time. Just a few large parts may be finished to specification or thousands of small parts may be handled by machines with revolving (tumbling) or vibratory motion. A medium is added to separate the workpieces and perform a finishing operation similar to that in polishing and buffing. The media which are used are listed in Table 25. Some of the media are used in conjunction with proprietary chemical compounds, or these compounds can be used by themselves. Most operations are carried out wet. Equipment may be made of wood or steel and may be lined with neoprene, vinyl, or polyurethane. Metal is removed in the process either as solid or dissolved ions depending on the specific compound used. The proprietary chemical compounds

TABLE 24. PRODUCTION TECHNIQUES FOR MECHANICAL POLISHING AND BUFFING OF METAL[(a)]

Material Finished	Polishing		Buffing		
	Rigid	Flexible	Satin	Cut-Down	Color
Aluminum	Glue or cold cement heated with aluminum oxide abrasive, grease bar applied to wheel, sewed buff canvas, felt, or leather wheel.	Aluminum oxide greaseless compound light bead of dry tripoli bar. Loose or ventilated buff or string wheel.	Aluminum oxide greaseless compound light bead of dry tripoli bar. Loose or ventilated buff or string wheel	Tripoli bar or liquid compound. Loose or ventilated buff.	Rouge, silica, unfused aluminum oxide bar or liquid compound. Loose or low density ventilated buff.
Brass	Glue or cold cement beaded with aluminum oxide abrasive, grease bar applied to wheel, sewed buffs, canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Sewed or loose buffs, canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or ventilated buff, string wheel.	Tripoli bar or liquid compound. Ventilated. Loose or sewed buffs.	Rouge, silica or unfused aluminum oxide bar or liquid compound. Loose or low density ventilated buffs.
Hard Chromium	Silicon carbide greaseless compound over glue sizing. Sewed buff, canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or sewed buffs. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose buff		Chrome green oxide or unfused aluminum oxide bar or liquid compound. Loose or ventilated buff.
Chromium Decorative Plate			Lubricated silica greaseless compound. Loose buff.	(For burnt areas) Combination fine fused and unfused aluminum oxide bar. Loose or ventilated buff.	Chrome green oxide unfused aluminum oxide bar. Loose or ventilated buff.
Copper		Aluminum oxide greaseless compound. Sewed buff. Canvas, felt or leather wheels.	Aluminum oxide greaseless compound. Loose or ventilated buff string wheel.	Tripoli bar or liquid compound. Loose sewed or ventilated buff.	Rouge, silica or unfused aluminum oxide bar or liquid compound. Loose or low density ventilated buff.
Copper Plate			Aluminum oxide greaseless compound. Loose or packed buff, string wheel.	Tripoli bar or liquid compound. Loose sewed or ventilated buff.	
Nickel and Nickel Alloys	Glue or cold cement beaded with aluminum oxide abrasive, sewed buff. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or sewed buffs. Canvas, felt, or leather wheels.	Aluminum oxide greaseless compound. Loose or ventilated buff.	Tripoli bar or liquid compound. Loose sewed or ventilated buff.	Chrome green oxide or unfused aluminum oxide bar or liquid compound. Loose or ventilated buff.
Nickel Plate Decorative			Aluminum oxide greaseless compound. Loose or ventilated buffs.		Lime bar, or chrome green oxide, or unfused aluminum oxide bar of liquid compound. Loose or low density ventilated buff.
Steel and Stainless Steel	Glue or cold cement beaded with aluminum oxide. Grease bar or energy cake applied to wheel. One or more operations required. Sewed buff. Canvas, leather or felt wheels.	Silicon carbide or aluminum oxide greaseless compound. Loose or sewed buffs. Canvas, felt, or leather wheels.	Silicon carbide or aluminum oxide greaseless compound. Loose or ventilated buff.	Aluminum oxide bar or liquid compound. Ventilated sewed, sisal finger or tampico buffs.	Chrome green oxide and/or unfused aluminum oxide bar or liquid compound. Loose or ventilated buffs.
Zinc		Aluminum oxide greaseless compound. Loose or sewed buff.	Aluminum oxide greaseless compound. Loose or ventilated buff.	Tripoli bar or liquid compound. Loose ventilated or sewed buffs.	Silica or unfused aluminum oxide and/or liquid compound. Loose or low density ventilated buffs.

(a) Metal Finishing Guidebook and Directory, 1974, p. 128 and 129, Metals and Plastics Publications, Inc. Hackensack, New York.

NOT REPRODUCIBLE

TABLE 25. MEDIA USED FOR MASS-FINISHING OPERATIONS(a)

Material	Standard Sizes(1)	Type of Operation	Abrasive Cutting(4)			Barrel Polishing(4)			Burnishing(4)		
			Ferrous	Non-ferrous	Plastics	Ferrous	Non-ferrous	Plastics	Ferrous	Non-ferrous	Plastics
Fused aluminum oxide shapes	#12 mesh to 2 in.	Wet	Y	Y	N	Y	Y	N	N	N	N
Aluminum oxide abrasive powders(2)	#16 mesh and smaller	Wet or dry	Y	Y	y	Y	Y	y	N	N	N
Bonded abrasives	1/16 to 2 in.	Wet	Y	Y	y	Y	Y	N	N	N	N
Ceramic bonded aluminum oxide	1/16 to 2 in.	Wet	Y	Y	N	Y	Y	N	N	N	N
Granite (mica-schist) chips(3)	1/16 to 1-1/4 in.	Wet	Y	Y	N	y	y	N	N	N	N
Flint stone(3)	1/16 to 2 in.	Wet	Y	Y	oy	y	y	N	N	N	N
Quartzite(3)	Various	Wet	Y	Y	N	y	y	N	N	N	N
Marble(3)	Various	Wet	Y	Y	N	y	y	N	N	N	N
Limestone chips(3)	1/16 to 1-1/4 in.	Wet	Y	Y	oy	Y	Y	N	N	N	N
Sand (sharp, builder's)	#8 mesh and finer	Wet or dry	Y	Y	oy	Y	Y	oy	N	N	N
Rolled zinc slugs	Various	Wet	yW	yW	N	YW	YW	N	Y	Y	N
Die-cast zinc slugs	Various	Wet	yW	yW	N	YW	YW	N	Y	Y	N
Soft steel balls and shapes	1/8 to 1/2 in.	Wet	yW	yW	N	YW	YW	N	Y	Y	N
Wooden balls and shapes	Various	Wet or dry	yW(6)	yW(6)	YW	yW(6)	yW(6)	YW	Y(6)	Y(6)	Y(6)
Vegetable ivory chips	Various	Wet or dry	yW(7)	yW(7)	N	yW(7)	yW(7)	N	Y	Y	N
Nut shells	Mixed sizes	Usually dry	N	N	YW	yW	yW	Y	Y	Y	Y
Hard steel balls and shapes	1/64 to 1/4 in.	Wet	N	N	N	N	N	N	Y	Y	N
Glass burnishing balls	New product	Wet	N	N	N	N	N	N		Y	
Macerated corn cobs(5)	Mixed-dust free	Dry	N	N	N	N	N	N	Y	Y	Y
Leather scrap	Various	Wet or dry	N	N	N	N	N	N	Y	Y	Y
Felt scrap	Various	Dry	N	N	N	N	N	N	Y	Y	Y
Molded iron powder and abrasive	New product	Wet	Y	Y	N	Y	Y	N	N	N	N

NOT REPRODUCIBLE

Footnotes for Table 25:

(1) Usual average dimensions. Other sizes available for special applications.
(2) Although occasionally used alone, particularly with parts which can be self-tumbled, this grain is usually mixed with other media.
(3) Available in quarried state or processed to remove sharp corners. Quarried form is only good for the very roughest of operations and becomes processed form after a few hours of use.
(4) Symbols indicate the following:

Y - most used
y - often used or possible use
N - never used
YW or yW - used with added fine abrasive

(5) Also used for drying after polishing or burnishing of all metals and plastics and as a medium extender for all media to reduce harsh action.
(6) With or without other media.
(7) See wood balls.

(a) Electroplating Engineering Handbook, Ed. by A. Kenneth Graham, 3rd Edition, 1971, Van Nostrand Bernhold Company, New York, p. 93.

are discarded into the drain leading to the water pollution control system or the sewer at the end of each mass finishing operation. Some media is also lost by abrasive action. The quantity of wastes (e.g., metal chips, soaps, etc.) contributed by mass finishing operations are estimated to be less than 0-3 percent of the total waste load on the basis that the greater portion of the materials pass through the waste treatment system (e.g., ions of the chemical compounds) or are directly discharged to sanitary sewers.

Miscellaneous Process Wastes

Filtration. One of the stringent requirements for producing electrodeposits is the maintenance of the plating bath by addition of chemical components lost by drag out with the plated parts and the purification of the solutions to remove suspended solids and organic contaminants as well as dissolved metals foreign to the bath. As a general routine, copper, nickel, zinc, tin, silver, gold, cadmium, or their alloy baths are continuously filtered at a rate which ranges from one-fourth to six times the bath volume per hour. The filter type and size has to be fitted for each type of solution, with volumes ranging from 600 to 2000 liters per square meter (15 to 50 gallons per square foot) of filter area per hour. The solids contained in a plating bath are such that they would easily clog the applied filter media, which are woven cloth or synthetic fibers, porous carbon, stoneware, yarnwound cartridges, and paper. To improve filtering efficiency and to ease the removal of the contaminated filter cake, a coating of 600 grams of filter aid per square meter (2 ounces per square foot) is applied onto the filter medium either before filtering operations are started or continuously by means of a proportioning pump.

Heavily contaminated baths, or baths which are not set up with individual filtering units, are normally batch treated in a separate purification tank by adding the filter aid directly to the bath together with other purifying agents (activated carbon, oxidizing agents). The filter aids most commonly used are diatomaceous earth, perlite, asbestos fibers, and alpha-cellulose fibers. Silica-containing filter aids are normally not used with fluoborate solutions because of the chemical attack on the silica. Asbestos fibers are used as a precoat under diatomaceous earth or mixed to about 20 percent with diatomaceous earth or cellulose for increased filtering rates and better adhesion of the filter cake to the filter membrane. All aids are supplied in grades varying from coarse to fine. Since most plating baths contain organic additives, which decompose during the operation, carbon is also added to the filter cake. The amount of carbon used ranges from 60 to 480 grams per 100 liters (1/2 to 4 pounds per each 100 gallons) of solution, depending on the degree of contamination or the available filter area. Generally, 900 grams of carbon are applied per square meter of filter area (3 oz/sq ft) from a slurry composed of the carbon and about 450 grams of filter aid.

Chemical purification is often used to remove inorganic impurities from plating baths. The methods are specific for the kind of impurity that is to be removed, the bath composition and the basis metal processed. For example, zinc dust is added to a zinc plating bath to chemically precipitate metals more noble than zinc (e.g., copper, iron). Zinc and lead present as foreign ions in cyanide plating baths can be removed by precipitation as the sulfides. Iron can be precipitated from nickel plating solutions by raising the pH and temperature of the solution and adding hydrogen peroxide to oxidize the iron. In each case the formed solids are removed by filtration.

Only the filter cake is disposed of when precoat filter membranes are used. When filter disks made of paper or yarn-wound cartridges are used, they are disposed of along with the filter cakes each time a filter is cleaned. For example, a solution volume of 4000 l (1000 gal) passed through a membrane filter once every hour at a rate of 1400 l/m^2 of filter area (35 gal/ft^2) would have a cake volume of about 30,000 cm^3 (1 ft^3) consisting of 3/4-filter aid and 1/4-activated carbon onto which dirt particles and precipitated metal salts are absorbed. The filter will also contain an equal volume of plating solution. At a density of 2 g/cm^3, the weight of disposable filter cake would be 60 kg (130 lb). This waste would then be discarded by backwashing the filter to a water pollution control facility, where available, or to the sewer. If yarn-wound cartridge or paper filter disks were used instead of a filter membrane, they would be discarded with general refuse.

Anode Wastes. Most electroplating solutions use soluble anodes as the source of the metal being plated. These dissolve at a rate approximately equal to the metal deposition rate. Insoluble anodes are used in precious-metal plating, anodizing, and electropolishing. Chromium plating is carried out with an insoluble lead-alloy (~94 percent lead, remainder antimony or tin) anode. A small loss of anode material is encountered by the formation of lead chromate on the anode surface during inactive periods. The film is brushed off and settles as a sludge on the bottom of the chromium tank or can be removed chemically in a solution of Rochelle salt and caustic soda. The life of a lead anode, nevertheless, is very long, in terms of years, and depends on how often and how long it is left in the bath without current flowing. A 10-year or more life for insoluble anodes is not uncommon.

Bags are used for most soluble anodes to collect insoluble anode materials, called anode sludge, during the electrochemical dissolution. The bags are loosely fitted around the anodes and are made of cotton, flannel, muslin, nylon, Dynel, and Vinyon. Blue African asbestos is used in iron plating baths at times. The life of an anode bag is dependent on the material and the type of solution in which it is used, but it should be used with several soluble anodes. Using the nickel plating bath of Line 1 of the 38-man model plant (Table B-1) as an example, 560 m^2 (6030 ft^2) of parts are plated daily in a tank containing 17,000 l (4500 gal) of nickel solution. The nickel anodes have an area of 16 m^2 (174 ft^2) and weigh 2090 kg (4610 lb). To produce a deposit of 15 µm (0.0066 inch) requires 74.8 kg/day (165 lb/day) of nickel and the annual weight sold as product is 18,700 kg (41,280 lb). In addition, about 15 percent of the nickel anodes or 2960 kg (6536 lb) are returned to the supplier as unusable scrap. The anode sludge accumulating in the anode bags is about 198 kg/year (436 lb/year) and is taken from the bags at each anode change, or every 22 days.

The anode bags have a service life of about 1 year. When discarded, they weigh 12.5 kg (27.5 lb) and contain 12.5 kg (27.5 lb) of nickel salts from the plating bath, and would normally be carried away weekly with the regular trash.

The anode scrap from this operation is estimated at about 9,550 kilograms (21,000 pounds) which, of course, would be sold to a nickel scrap dealer.

Although this example gives an indication of the volume of waste generated by one plating operation, it is by no means universal. Nickel anodes are also manufactured in small "rounds", about 1 inch in diameter and 1/4-inch thick. These anodes are held in insoluble baskets, requiring less nickel material because of much greater active surface area. These nickel anodes are designed such that they will use up almost 100 percent of the anode, resulting in no anode scrap. The anode bag consumption is somewhat greater than with rolled anodes, whereas the anode sludge formed is about the same. Other anode metals may be formed into balls, rolled into sheets or cast as slabs, and all contain varying additives to enhance dissolution or activity.

Plating Racks. The function of a plating rack is to hold the workpiece to be plated and to conduct current to the workpieces. Depending on the shape and size of the part to be plated, a rack can be a simple wire arrangement or a complicated fixture, or even be supplied with auxiliary anodes. Racks are made of materials with high current-carrying capacity, copper being the one most widely used. Titanium is used for anodizing and as rack tips. Other materials used in the construction of racks are brass, bronze, nickel, steel, stainless steel, lead, Monel, and aluminum. The bare metals are insulated with rack coatings by dipping the rack into a two-coat system and baking. Coating materials, listed in Table 46, have a limited life because of the corrosive nature of the plating solutions. Any separation of the coating from the metal causes drag in of unwanted chemicals into the plating baths, which is detrimental to the deposit. For that reason, many electroplating facilities are equipped with a rack department; here, new racks are designed and constructed, while old racks are repaired (1) by removing the old coating and applying a new insulating coating, and (2) by cleaning the contact points of the electrodeposited metal. The rack coating is normally softened with an organic solvent and then mechanically stripped. The waste coating leaves the plant destined for land disposal. The metal removed from or with the rack tips is also discarded. Before recoating the racks, the basis metal is cleaned, normally by grit blasting, which would add small amounts of metallic wastes to the disposal load of such a plant. There are rack specialty shops which supply that part of the industry too small to have its own rack department.

Tank Linings. Plating tanks are generally protected from corrosion by various linings. The linings are made of rubbers and plastics, thermosetting resins and metallics, which in most cases is lead. The nonmetallic linings also act to insulate the tanks against stray currents, whereas the lead lining is often used as the cathode material in anodizing and electropolishing. Linings may have to be replaced occasionally due to excessive damage from tears or extreme heat. Small defects to the

TABLE 26. DATA ON RACK INSULATING MATERIALS(1)

Material	Method of Application	Primer Used	Form	Adhesion	Method of Curing	Repair	Resistance to Mechanical Injury	Solution Tolerance*
Vinyl plastisols	Dip	Yes	Paste	Very good	Bake	Redip, tape or air-dry material	Very good	Very good in all plating solutions, acids and alkalies; good in degreasers.
Hard rubber	Wrap	Yes	Sheet	Poor	Bake	Tape or air-dry material	Easily cracked	Good in all plating solutions except chromium; not good in degreasers.
Soft rubber	Wrap, dip or spray	Yes	Sheet or liquid	Good	Bake	Tape or air-dry material	Good	Good in all plating solutions except chromium; not good in degreasers.
Neoprene	Dip	No	Liquid	Good	Heat-dry	Tape or air-dry material	Good	Good in all plating solutions; fair in chromium; not good in degreasers.
Air-dry plastics	Dip	Usually none	Liquid	Usually good	Air-dry; some better if baked	Easily repaired in spots	Reasonably good	Good in general; most types good in chromium; not good in degreasers.
Wrap tape, nonadhesive	Wrap	No	Tape	None	Air-dry, cement at ends	Easily retaped	Poor	Good for temporary racks, short runs or repairs; not good in degreaser.
Pressure-sensitive tape	Wrap	No	Tape	Fair	None	Very easily retaped	Poor	Good for temporary racks, short runs or repairs; not good in strong alkalies-chrome.
Waxes	Dip	No	Liquid when hot	Poor	Cool	Very easy	Very poor	Good except in very hot solutions and strong alkalies.

(1) Electroplating Engineering Handbook, 3rd Ed., A. K. Graham, Editor, Van Nostrand Kernhold Company, New York, p. 600.

linings can be repaired. The extent of the disposal of linings cannot be ascertained because repair of linings is generally carried out by the supplier of tanks.

Rejects, Used Equipment, and Supplies. The multiple steps performed in the electroplating and metal finishing industry have to be carefully watched and controlled, since small variations may cause defects which may result in the rejection of the finished products. Depending on their value, parts may be salvaged by stripping the coating, refinishing the basis metal, and replating. Items where this may occur are, for example, automotive bumpers and silver- and gold-plated products. Where it is uneconomical or the basis metal is adversely affected by stripping, parts are not salvaged for replating. Zinc die castings are scrapped and remelted without stripping the coating. Plated steel, brass, or bronze parts are also sold as scrap. It is not unusual, however, for small quantities of off-spec products to be discarded. Stripping solutions differ depending on the coating or coatings to be deposited and the kind of metal to be coated. They may be either chemical or electrochemical in nature. Some of the chemicals used are: inorganic acids, chromates, peroxides, hydroxides and salts of peracids, cyanides, and some proprietary organic acid salts. The stripped metals are present as ions at fairly strong concentrations (>1M) in solutions which may be fed to the wastewater treatment plant or discarded with the water discharge from the plant. Quantitative determinations of the chemicals used for stripping and the metals lost by stripping are not possible since the published data are lacking and the information contributed by the industry on the use of chemicals and discharge of metal ions from stripping was insufficient.

As in all manufacturing, production equipment has to be replaced or repaired. Solutions are circulated through filters, heat exchangers, and purification equipment, requiring the replacement of pump parts, valves, pipes, etc. Because of the corrosivity of the plating baths at elevated temperatures, replacement parts may be needed more often than in other process operations. Immersion heaters, heating coils, anode baskets made of titanium or plastic-coated steel, filters, temperature controls, pH meters, conductivity bridges, spray and mist nozzles, anode and cathode bus bars, (which supply electric current to the plating process), moving and hydraulic parts of conveyors or automatic machines, duct hoods, piping, and exhaust fans handling corrosive fumes, all have limited life and need occasional replacement or repair. Undisclosed amounts of these materials may either be collected and sold as metal scrap or be discarded as waste.

Since electroplating and metal finishing operations always consume chemicals, it is necessary for facilities conducting these operations to store a certain amount of these materials. Acids are contained in carboys; while alkaline cleaning compounds, chromic acid, and cyanide-containing salts come in drums ranging in volume from 20 to 300 liters (5 to 75 gallons). Other plating salts, such as nickel sulfate, carbonates, phosphates, etc., come in 50-kg (100 lb) bags; liquid fluoride, fluoborate, and sulfamate solutions are stored in plastic or lined steel containers. Organic additives for plating baths come in glass or plastic bottles. The large drums, 300-1 (75 gal), cylinders of gaseous chemicals (chlorine, sulfur dioxide, and ammonia, which are used in waste treatment), and carboys are returned to the supplier, while all other packaging material is disposed of with the weekly refuse collection. Chemical salts are caught in the linings of bags, and bottles are not rinsed after being emptied, which causes small amounts of hazardous chemicals to be disposed of with the packaging.

Oil Emulsions. In some process operations, oil emulsions are used in the final step of the metal finishing operation to provide additional corrosion protection for the workpieces. Cutting oils and soluble oil coolants are used in mechanical operations which are sometimes associated with metal finishing shops become part of the shop waste. These wastes are handled in waste treatment systems by oil skimmers or precipitated with ferrous or aluminum salts and separated in clarifiers or air-flotation equipment. Thus they are a part of the water pollution control sludge.

Paints and Paint Solvents. Paint and paint solvents are in many ways like oil emulsions and are removed by destroying [illegible] emulsifying agents and separating and settling the solids. Electropainting operations, the major source of paint wastes, sometimes use ultrafiltration to eliminate waste discharge from the painting process. The use of paints, however, is not a common part of electroplating and metal finishing facilities.

Stop-Offs. In some cases, parts are only plated partially or have different finishes in different areas. Areas which are not to be finished or which are to be finished differently are masked. Masking may be accomplished with inert reusable materials, or tapes or stop-off paints which are stripped after the process is completed, by either pulling the tape or dissolving the stop-off with a solvent. Photo resists and masks are used in the printed circuit industry. Stop-offs find their largest application in hard chrome plating. Used organic stop-offs, solvents and photo resists are collected and returned to the supplier while tapes are disposed of with the weekly refuse.

Oil to Replenish Hydraulic Units. The use of large hydraulically operated plating and finishing machines leads occasionally to oil spills. It is customary to soak up such spills with an absorbing material such as sawdust or corncobs. Incineration and land disposal are the two ways of handling such wastes, the latter being most predominant.

Degreaser Sludges

Vapor degreasing is used as a part of the electroplating and metal finishing operation to remove soils (oils, grease, buffing compounds, etc.) from the parts to be processed. Degreasers may be small and manually operated or can be large automated machines. The type of solvent used depends on the soil and the material to be cleaned (Table 27). The spent solvents are generally recovered by distillation. A distillation unit may be an integral part of the degreasing unit, or the solvent may be collected and sealed in drums upon cleanout of the degreaser and returned to the supplier or a scavenger. The frequency of degreaser cleanout depends on the type and quantity of soil removed and varies from shop to

TABLE 27. TYPICAL APPLICATIONS FOR VAPOR-DEGREASING SOLVENTS(1)

Application	Solvent	Approximate Vapor Temperature, F	Factors Affecting Selection
Removal of soils from parts	Trichlorethylene	188	Most commonly used degreasing solvent
Removal of slightly soluble (high melting) soils	Perchlorethylene	250	Used where higher operating temperature is desirable
Removal of water films from metals	Perchlorethylene	250	Rapid and complete drying in one operation
Cleaning coils and components for electric motors	Methyl chloroform	165	Solvent must not damage wire coating or sealing agents. Requires special equipment design. Selection should be based on preliminary trials
	Trichloro-trifluoroethane	118	
	Perchlorethylene	250	
Cleaning temperature-sensitive materials	Methylene chloride	104	Used where parts must not be exposed to higher vapor temperatures during cleaning. Special corrosion resistant equipment is required
	Trichloro-trifluoroethane	118	
Cleaning components for rockets or missiles	Trichlorethylene	188	Cleaned parts must be free of soils or residues which might react with oxidizers
Cleaning with ultrasonics	Trichlorethylene	188	For cleaning efficiency beyond that obtained from standard vapor degreasing. Solvent must be kept clean by continuous distillation and filtration during use. Selection should be based on preliminary trials
	Perchlorethylene	250	
	Methylene chloride	104	
	Fluorinated hydrocarbon	118	

(1) Metal Finishing Guidebook and Directory, 1974 Edition, Metals and Plastics Publishing, Inc., Hackensack, New Jersey

shop. Some criteria have been established to determine when a degreaser should be cleaned. Most commonly, the need for cleaning the degreaser is established when the boiling point of the contaminated solvent is from 5 to 10 degrees above the boiling point of the pure solvent. In most shops, experience shows that this will take place at nearly consistent intervals. The sludge and solids collected at the bottom of the degreasing tank are removed and disposed of in a landfill. The solvent is purified by distillation either in-house or at the supplier's facilities. Other loss may occur through leaks or spill. Vaporization to the surrounding air is minimal. The threshold limit is normally 100 ppm in air by volume.

Salt Precipitates from Electroless Nickel Bath Regeneration

Electroless plating is a method by which metals are deposited onto other metals or nonmetals such as plastics by autocatalytic redox reactions in solution. Electroless plating for industrial applications is performed to provide a uniform coating thickness on all areas of a part (which is not the case with electrodeposition), to provide reduced porosity, and to improve the corrosion and wear resistance resulting from an ultrimicro cyrstalline alloy of the metal with phosphorus. No applications are known for arsenic, chromium, and iron electroless plating. Catalytic gold and palladium electorless plating are used to a small extent and cobalt electroless plating finds some application where magnetic properties are desired. Catalytic copper electroless plating finds its application mostly in the fabrication of printed circuits, plating on plastics, and other nonconductors.

The catalytic nickel electroless plating baths, finding frequent applications, are based on the reducing properties of the hypophosphite anion:

$$[H_2PO_2]^- + H_2O \xrightarrow{\text{Catal. }(Ni^o)} H^+ + HPO_3^{2-} + 2H \text{ (Catalyst)}$$

$$Ni^{2+} + 2H \text{ (Catalyst)} \longrightarrow Ni^o + 2H^+$$

$$[H_2PO_2]^- + H \text{ (Catalyst)} \longrightarrow H_2O + OH^- + P$$

$$[H_2PO_2]^- + H_2O \xrightarrow{\text{Catal. }(Ni^o)} H^+ + HPO_3^{2-} + H_2$$

A continuous increase in phosphite as indicated by these reactions, causes the bath to become inoperable, and it must be discarded, as is normally the case with small installations. The bath is returned to the supplier for recovery of valuable nickel. When production rates are high, however, it is economically advantageous to regenerate the bath. Regeneration steps include the addition of water-insoluble nickel salts, such as hydroxides or carbonates and the removal of the phosphite ions by ion exchange. Most successful operational regeneration processes are based on the chemical precipitation of the phosphite anion. For example, the addition of calcium sulfate and hydrated lime to increase the solution pH to about 6 precipitates calcium orthophosphite. Sodium sulfate which builds up during the regeneration process is separated by freezing at 0 to 5 C (32 to 42 F) and removed by centrifuging, filtering, or decanting of the bath. For each kg of catalytically deposited nickel approximately 2.5 kg of calcium orthophosphite and 1.1 kg of sodium sulfate are produced. These wastes would be disposed of in a landfill.

Waste Projections

Estimates of the total industry and potentially hazardous wastes expected from the electroplating and metal finishing industry job shops were derived from the three model plants, the data discussed in Section I, and the data collected from industry (see Appendix G).

Model Plants

Because of the paucity of data obtained by the industry survey, it was necessary to develop a series of model plants to calculate the quantity of wastes rather than just use the data generated from the survey.

For the purpose of developing model plants for the electroplating and metal finishing industry and the projections of total industry and potentially hazardous waste, certain assumptions and conditions were recognized. The principal considerations included the following:

Plant size
Product mix
Plant operating criteria.

The selection of plant size was based on the data shown in Table 2 of Section I, which shows the distribution of plants in terms of the number of employees. The size (number of employees) ranges and the percentage distribution are as follows:

Employees	Distribution Percen
1-4	12.04
5-10	26.69
11-25	30.56
26-50	19.74
51-75	4.20
76-100	3.79
101-150	1.56
151-250	1.09
251-500	0.33

From this table, three model plants were developed. Plant A represents the average, or medium, size job shop with a work force of between 26 and 50 employees and would produce about 34 percent of the total output from the 552 electroplating and metal finishing job shops. The other two model plants would represent the manufacturing facilities with fewer or more employees than 26 to 50, respectively.

Model Plant B, small shops, encompasses 567 job shops with between 5 and 10 employees and 646 job shops with an employment of 11 to 25 people. The combined number of 1,213 shops, just more than half of the industry total (Table 2), is estimated to produce less than 26 percent of the total output. Job shops employing fewer than 5 employees were not included in the model plant for the purpose of projecting waste quantities for the following reasons:

(1) They are estimated to produce approximately 1 percent of the electroplating and metal finishing output. For that reason they generate relatively small quantities of waste per plant and are exempted from conforming to the effluent limitations guidelines for the electroplating and metal finishing industry in 1977. Consequently, these plants do not generate any water pollution control waste.

(2) Even though process wastes occur in all manufacturing operations, no matter what size plant, the disposal of these wastes is treated in an entirely different fashion. Anode scrap, plating racks, and other metallic parts are collected in barrels and sold to scrap dealers. Rejects are returned to the customer. Anode sludge and filter cakes from small portable paper filters are rinsed and flushed to the sewer. The small number of employees does not allow for any preplating or postplating operations such as polishing, buffing, grinding, etc. Consequently, none of these process wastes are being generated.

(3) Since there is no polishing or buffing a degreaser is not required. Oils, waxes, and dirt on the parts to be plated are removed entirely by the use of soak and electrolytic cleaners. Degreaser sludges, therefore, are not present.

(4) Spent electroless nickel plating solutions or baths that require regeneration, if used in the 1-4 employee plant, would be of small volume and beyond the scope of the plant to process and would be discharged to the sewer or returned to the supplier.

Model plant C represents all facilities employing from 51 to 500 persons and consists of 232 shops estimated to be responsible for less than 40 percent of the total job shop production. Close to three-fourths of the 232 shops employ between 51 and 100 employees.

Thus, model plants were developed for 38 employees (medium or average size plant), for 16 employees (small size plant), and for 87 employees (large size plant).

After the plant sizes were chosen, the volume of production, the plating processes to be operated by the plant, and the type of equipment needed for that production rate were determined. The fact that two-thirds of all metal finishing involves the deposition of copper, nickel, chromium, and zinc and that the majority of products are made of ferrous or copper-based alloys was the determining factor in the selection of the electroplating and metal finishing processes. Frequently occurring processes such as phosphating and anodizing were also considered as was electroless nickel plating, producing atypical wastes, and these were included in the medium and large size plants. It is unlikely that even the largest size plant would have all the plating and finishing processes at its disposal.

Equipment. The type of basis metal and the size, shape, and finish of the workpieces determine the size of equipment needed, the sequences of the process operations, and whether the equipment should be automated.

Each job shop is likely to serve more than one industry, and therefore requires equipment adaptable to a continuous change of products. Under such conditions, small shops are likely to have a large number of smaller tanks for depositing a variety of metals. The same preplating or postplating solutions, such as cleaners, pickles, and chromating solutions, etc., are often used for more than one plating operation. The needed flexibility of processing and the economics of small volume items to be finished preclude the use of much automated equipment. As the production volume of a job shop increases, greater quantities of the same parts, and different parts being finished by the same process, allow for the automation of some, if not all, of the production. The introduction of automated equipment is equivalent to an increased output per man hour, but not necessarily in a direct ratio, as can be seen in Table 29. Two men produce 120 m^2 of Cu-Ni-Cr plating by manual operation whereas four men produce 320 m^2 doing the same operation in an automatic machine. Although the actual plating times are the same to deposit the same quantity of metal, the solution volumes of the automated equipment are better utilized, i.e., larger area plated per unit volume of solution, transfer times from tank to tank are normalized, and racking and unracking and drying of the workpieces with specially designed racks for each item becomes much more efficient. When the products do not require racking but can be processed as bulk volume in barrels, production can be significantly increased. A good example of such a process would be the finishing of ferrous screw machine products.

Process Steps. The plant operating criteria were then matched to the product mix and the process descriptions (p. 24). Several assumptions were made in selecting the process steps, taking into account old and new equipment. For example, three-stage countercurrent rinses would be found in most modern plants, but the single rinses used in older plants, or because of the lack of space, would require much greater volumes of water. The result is a reduced ion concentration in the waste stream causing inefficient removal of toxic materials as solid waste. For two chromium waste streams, one containing 300 mg/l and the other 3 mg/l, the metal removal efficiency would be 99.8 and 83.3 percent, respectively. if the amount of chromium in the effluent were 0.5 mg/l. Or, expressed as a solid waste, the 300 mg/l waste stream produces about 20 percent more chromium hydroxide waste. The water flow rates* were determined on the basis of the composition of the process bath and a set maximum concentration of 37 mg/l in the rinses of the plating baths other than chromium, which was allowed a concentration of 15 mg/l, and rinses after cleaners and acid dips, for which concentrations of 750 mg/l were permitted in the last rinse following each process step. A rinse factor of 0.7 was used in calculating the water flow to compensate for density, viscosity, temperature, and transfer time effects. The cleaner and acid consumptions were based on general plating technology, requiring that these solutions would be dumped after losing their effective strengths at some production intervals. Drag out rates depend greatly on the size and shape of the processed parts, the transfer time from tank to tank, and the viscosity, temperature, and density of the solutions, and may vary from 0.14 l/m^2 (0.4 gal/1000 ft^2) for vertical well drained parts to more than 8 l/m^2 (24 gal/1000 ft^2) for cup-shaped, very poorly drained parts. Average drag out rates of 1 l/m^2 (3 gal/1000 ft^2) for rack operations and 1.67 l/m^2 (5 gal/1000 ft^2) for barrel operations were selected.

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* Concentrations and water flow rates are based upon the composition of the plating baths and the water flow rates permitted by Effluent Limitation Guidelines.

The correlations among plants with regard to characteristics and waste generation rates, as reported by industry, were also analyzed at considerable length, as were any potential correlations of operating conditions. The characteristics examined for correlation included:

Number of employees
Power consumption
Installed rectifier capacity
Area plated
Plant operating rate.

From our analysis, no applicable correlation was found. This was attributed to the multitude of operating conditions characteristic of the electroplating and metal finishing industry. According to the process descriptions given earlier (see p. 24), more than 600 plating processes are possible. Furthermore, each plating process may be different or a different number of cleaners may be used; the acids may vary in composition as well as ionic strength,or may be used with or without current; and even the plating baths may vary in composition. A plot of one characteristic examined, the area plated versus either the installed rectifier capacity or power consumption (i.e., actual electricity used), showed so wide a spread of data points that no relationships among plants could be developed. The wide spread in the data would appear to be the result of interaction of other factors, such as the degree of automation, the number of process lines, the coating thickness, the varying power consumption rates for different deposits, and the basic efficiency of operation.

Nevertheless, the reported industry data were taken into consideration in the design of the model plants. The average working time per week was 70 hours. The production volume of each line was estimated from that time basis, allowing for down time for solution and equipment maintenance, start-up time, etc. Automated type equipment is likely to have longer operating times than manual equipment, especially in the small shops where all plating tanks are not used all the time and not to full capacity. Such variations make it difficult to set up production rates on an hourly basis. A 24-hour day was therefore used as the time basis indicating that equipment may be utilized from a few hours to 24 hours per day. The man power assigned to each line would be the determining factor.

In summary, the following considerations were given to the development of the model plants:

- Plant size
  - specify the number of employees
  - industry production rates
- Product mix
  - specify the plating process, consisting of a major portion of copper, nickel, chromium, and zink plating; with anodizing, electroless nickel, cadmium and other finishes represented in minor portion of the product mix.
  - select a mix of automated and manual operations compatible with the number of employees
  - specify the base metals to be finished
- Plant operating criteria based on the electroplating engineering technology, including
  - preplating, plating, and postplating steps
  - solution compositions
  - bath dump rates, spills, and leaks
  - area plated
  - tank sizes or solution volumes
  - solution drag out rates
  - rinse water usage
  - materials consumption
  - plant operating times
- Industry reported data from questionnaires
- Design the water pollution control systems based on chemical treatment technology, the prevailing present practice in the industry, and derive the sludge production rates
- Derive rates of waste generation during production
- Determine the degree and type of finishing required for the basis metal and derive waste generation rates.

The average or medium size plant, Model Plant A, is characterized by the data given in Table 28. It consists of nine process lines with a total production rate of 3400 m^2/day (36,576 ft^2/day), plating copper, nickel, chromium, zinc, and cadmium with additional phosphating of steel, anodizing of aluminum and an electroless nickel plating operation. The processing rate differs from the production rate by the number of coatings steps for each line. For example, in Line (1) the total production rate is 560 m^2/day, which is being processed through 3 electrodeposition baths, namely copper, nickel, and chromium, in succession for a processed area of 3 x 560 = 1,680 m^2/day. Or in Line (5) where the production rate of 160 m^2/day yields a process rate of 2 x 160 = 320 m^2/day taking into account the cadmium deposition and the chromate conversion coating steps. Steels, brass, and aluminum are the base metals to be finished. Detailed calculations for the operation of the model plant are given in Appendix B.

Model Plant B, which is representative of the smaller job shops with 5 to 25 employees, is defined in Table 29. Six lines, electrodepositing

TABLE 28. PLATING OPERATIONS FOR MODEL PLANT A (INTERMEDIATE)

Representing Job Shops with 26 to 50 Employees (Industry Average)

Line or Operation	Assumed Production Rate,		Processing Rate,		Rinse(1) Water Allowed,		Employees	
	m^2/day	ft^2/day	m^2/day	ft^2/day	l/day	gal/day	Rack, Unrack, Plating, etc.	Others
1) Automatic Rack Cu(CN)-Ni-Cr	560	6,024	1,680	18,072	63,590	16,800	7	
2) Manual Rack Cu(CN)-Ni-Cr	160	1,720	480	5,160	18,170	4,800	3	
3) Automatic Rack Zn(CN) +	800	8,608	1,600	17,216	45,950	12,140	5	
4) Automatic Barrel Zn(CN) + Chromating	480	5,160	960	10,320	45,950	12,140	3	
5) Manual Barrel Cd(CN) + Chromating	160	1,720	320	3,440	16,810	4,440	1	
6) Manual Rack Hard Cr	80	864	80	864	10,370	2,740	1	
7) Manual Rack Al Anodizing (+ Bright Dip + Nickel - Acetate Seal)	600	6,456	1,800	19,368	54,960	14,520	6	
8) Automatic Barrel Zn Phosphating	400	4,304	400	4,304	24,910	6,580	2	
9) Manual Electroless Nickel Rack Plating	160	1,720	160	1,720	12,040	3,180	2	
Combined Lines	3,400	36,576	7,480	80,464	292,750	77,340	30	8 (see below)

Other Employees:	
Supervision (Plating)	1
Supervision + W.T.	1
Lab Analysis (W.T. + Plating)	1
Rack-Repair-Stripping	1
Maintenance	1
Misc. Job in Plating Shop	1
Clerical	2
Subtotal	8
TOTAL EMPLOYMENT	38

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(1) Based on a water use of 80 l/m^2 (1,964 gal/1000 ft^2) of area processed.

TABLE 29. PLATING OPERATIONS FOR MODEL PLANT B (SMALL)

Representing Job Shops with 5 to 25 Employees

Line or Operation	Assumed Production Rate, m^2/day	Assumed Production Rate, ft^2/day	Processing Rate, m^2/day	Processing Rate, ft^2/day	Rinse Water Allowed,(1) l/day	Rinse Water Allowed,(1) gal/day	Employees: Rack, Unrack, Plating, etc.
(1) Automatic rack Cu(CN)-Ni-Cr	320	3,440	960	10,328	76,800	20,280	4
(2) Manual rack Cu(CN)-Ni-Cr	120	1,288	360	3,872	28,800	7,600	2
(3) Automatic barrel Zn(CN) + chromating	280	3,016	560	6,024	44,800	11,840	2
(4) Manual barrel Cd(w) + chromating	160	1,720	320	3,440	25,600	6,760	1
(5) Manual rack Al Anodizing (+ bright dip + nickel acetate seal)	160	1,720	480	5,168	38,400	10,160	2
(6) Automatic barrel Zn-phosphating	400	4,304	400	4,304	32,000	8,440	2
Combined lines	1,440	15,488	3,080	33,136	246,400	65,080	13
Management							1
Supervision-maintenance							1
Clerical							1
Total employment							16

(1) **Based on a water use of 80 l/m^2 (1964 gal/1000 sq ft).**

copper, nickel, chromium, zinc, and cadmium, plus aluminum anodizing and zinc phosphating, have a production rate of 1,440 m^2/day (15,488 ft^2/day) and a processing rate of 3,080 m^2/day (33,136 ft^2/day). The base metals to be finished are steel, brass, and aluminum. Details for plant operation and waste generation are given in Appendix C.

Model Plant C, which is representative of the larger job shops with 51 or more employees, is defined in Table 30. In this largest plant copper, nickel, chromium, zinc, cadmium, tin-copper and lead-tin alloys are deposited in seven lines. One additional line is for anodizing, another for phosphating, and a third for electroless nickel plating bringing the total to 10 lines with a production rate of 6,960 m^2/day (74,904 ft^2/day) or a process rate of 17,120 m^2/day (184,240 ft^2/day). In addition to the usual base metals, steel, brass, and aluminum, zinc die-castings are also finished. Calculations for the operation of the plant, materials consumption, and waste generation are given in Appendix D.

Discussion of Model Plant Design

The characteristics of the model plant designs are discussed below. Figure 5 shows the wastewater streams from each of the nine plating or finishing lines of Model Plant A and the daily flow rates of the five combined streams each going to its specific water pollution treatment system, followed by neutralization and precipitation of the heavy metals. After liquids-solids separation in the clarifier, 314,530 l/day (83,100 gal/day) of effluent are discharged to a stream or sewer and 835 l/day (220 gal/day) of sludge with a 20 percent solids content would be disposed of by landfill means. Details are given in Section III.

Each process line is then broken down into process steps. Line 1, for example, identified as a Cu-Ni-Cr automatic rack line includes the following process sequence:

Hot alkali soak clean
Single rinse
Electrolytic anodic clean
Single rinse
Sulfuric acid pickle
Single rinse
Copper cyanide plate
Countercurrent rinse, 2 stations
Sulfuric acid dip
Single rinse
Nickel plate
Countercurrent rinse, 2 stations
Chromium plate
Countercurrent rinse, 2 stations
Hot-air dry

The drag out rate for an average shaped part was taken to be 12 l/100 m^2 (3 gal/1000 ft^2). With a production rate of 560 m^2/day (6,024 ft^2/day), the drag out rate is 68.5 l/day (18.1 gal/Yda0 for each of the above process

TABLE 30. PLATING OPERATIONS FOR MODEL PLANT C (LARGE)

Representing Job Shops with More than 50 Employees

Line or Operation	Assumed Production Rate, m^2/day	Assumed Production Rate, ft^2/day	Processing Rate, m^2/day	Processing Rate, ft^2/day	Rinse Water Allowed,(1) l/day	Rinse Water Allowed,(1) gal/day	Employees Rack, Unrack, Plating, etc.
(1) Automatic rack (3 lines) Cu(CN)-Ni-Cr	1680	18,080	5600	60,264	448,000	118,360	21
(2) Manual rack (3 lines) Cu(CN)-Ni-Cr	480	5,168	1660	17.216	128,000	33,840	9
(3) Automatic rack Zn(CN) + chromating	800	8,608	1600	17,216	128,000	33,840	5
(4) Automatic barrel (2 lines) Zn(CN) + chromating	960	10,328	1928	20,664	153,600	40,600	6
(5) Manual barrel, combined 1/2 Cd(CN) + chromating 1/2 Sn-Cu(CN)	320	3,440	480	5,168	38,400	10,160	2
(6) Manual rack Hard Cr	160	1,720	160	1,720	12,800	3,400	2
(7) Manual rack, Al-Anodizing (+ bright dip + Ni-acetate seal)	1200	12,912	3600	38,744	288,000	76,080	12
(8) Automatic barrel Zn-phospating	400	4,304	400	4,304	32,000	8,480	2
(9) Manual electroless Ni	160	1,720	160	1,720	12,800	3,400	2
(10) Automatic rack Pb-Sn-alloy (BF_4^-)	800	8,608	1600	17,216	128,000	33,840	7

(1) Based on a water use of 80 l/m^2 (1,964 gal/1000 sq ft) of area processes.

TABLE 30. (continued)

Line or Operation	Assumed Production Rate, m^2/day	Assumed Production Rate, ft^2/day	Processing Rate, m^2/day	Processing Rate, ft^2/day	Rinse Water Allowed, 1/day	Rinse Water Allowed, gal/day	Employees Rack, Unrack, Plating, etc.
Combined Lines	6960	74,904	17,120	184,240	1,369,000	361,840	68
Other Employees:							
Supervision plating							3
Waste treatment							2
Lab analysis							3
Rack-repair-stripping							2
Maintenance							2
Miscellaneous							2
Clerical							3
Management							2
Subtotal							19
Total Plant							87

PROCESS LINES	WASTE STREAMS(1)	RINSE AND DUMP VOLUME,(2) gal/day
Line 1 Cu-Ni-Cr (Auto.)	CuCN	1,400
	Ni	2,120
	Cr	3,900
	A/A	9,640
Line 1 Cu-Ni-Cr	CuCN	400
	Ni	610
	Cr	1,100
	A/A	3,370
Line 3 $Zn(CN)_2$ (Auto.)	ZnCN	2,850
	Chromate	930
	A/A	8,510
Line 4 $Zn(CN)_2$	$Zn(CN)_2$	2,850
	Chromate	920
	A/A	8,550
Line 5 $Cd(CN)_2$	$Cd(CN)_2$	880
	Chromate	320
	A/A	3,160
Line 6 Cr	Cr	560
	A/A	2,200
Line 7 Anodize	Bright Dip	2,080
	Anodize	2,000
	Ni Acet.	2,840
	A/A	7,970
Line 8 Phosphate	Zn Phosphate	1,060
	A/A	5,580
	CrO_3 Seal	50
Line 9 Electro-less Ni	Ni	230
	A/A	2,990

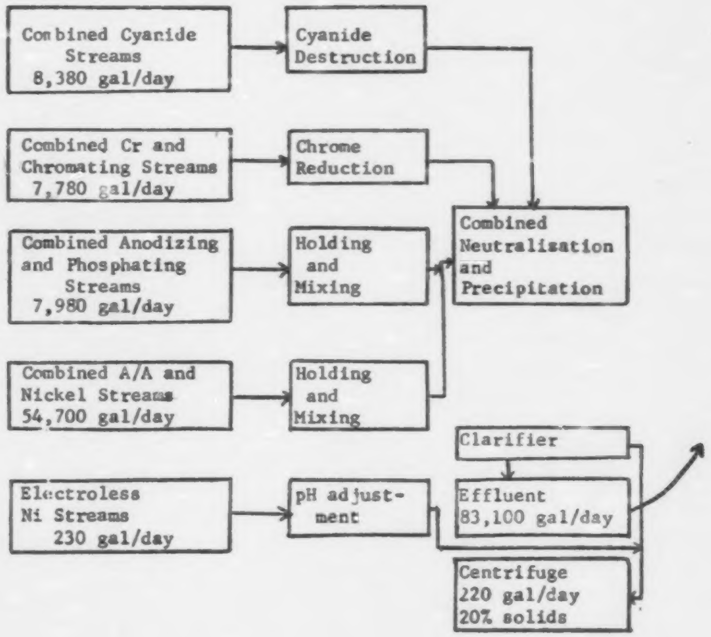
Combined Cyanide Streams 8,380 gal/day
Cyanide Destruction
Combined Cr and Chromating Streams 7,780 gal/day
Chrome Reduction
Combined Anodizing and Phosphating Streams 7,980 gal/day
Holding and Mixing
Combined Neutralization and Precipitation
Combined A/A and Nickel Streams 54,700 gal/day
Holding and Mixing
Clarifier
Electroless Ni Streams 230 gal/day
pH adjust-ment
Effluent 83,100 gal/day
Centrifuge 220 gal/day 20% solids

FIGURE 5. FEATURES OF SLUDGE GENERATION IN MODEL PLANT A

*A/A = acid/alkali

stations. The hot alkali soak cleaner is made up at a concentration of 60 g/l (8 oz/gal) of proprietary compound in a tank having a volume of 7,570 liters (2000 gal). A rinse water flow of 7,850 l/day (2,070 gal/day) is calculated on the basis of the initial salt concentration, the drag out rate, the allowable salt concentration in the rinse following the cleaner, and a rinsing efficiency of 70 percent.

The spent cleaner is dumped every 25 working days, containing 75 percent of the original constituents of the bath, 25 percent having been used up during production. The proportionate loss to the waste stream is:

	Make-up Concentration			Dump Concentration	
	Weight percent	g/l	oz/gal	g/l	oz/gal
NaOH	35	21.0	2.8	15.8	2.1
$NaSiO_3$	25	15.0	2.0	11.3	1.5
Na_2CO_3	22	13.2	1.76	9.9	1.32
$Na_3PO_4 \cdot 12H_2O$	12	7.2	0.96	5.4	0.72

The cleaner dump rate of 2,000 gal/25 days = 80 gal/day is metered into the water treatment system and when multiplied by the concentration of the constituent of the bath gives the waste load. For example, the sodium hydroxide lost from this process step to waste is 4.76 kg/day or 10.5 lb/day. The same calculation is carried out for each constituent of the process solutions, giving the total concentration of ions in the waste streams. Acids and bases tend to neutralize in the treatment system. Most anions are discharged in the effluent, and the metals are precipitated as hydroxides after subtraction of the metal ion concentrations that are dissolved in the effluent (see Table 31).

The net results of the model plant sludge waste derivations are summarized in a brief and simplified form in Table 32. The detailed calculations supporting the data in Table 33 are given in Appendixes D and E. The table presents information bearing only on wastes from the water pollution control system.

A detailed review of all model process operations produced estimates of other process wastes. The types and fates of wastes developed for the medium-size model plant operation are listed in Tables 34 and 35. It will be noted from the tables that some wastes are considered to be recycled or reclaimed. These assumptions are in accord with current practices in some shops reflecting practical economics.

One of the points worthy of discussion is the waste load produced with each regeneration of the electroless nickel bath. Electroless nickel plating was included as representative of the industry and it was further assumed that the bath would be regenerated in-house. Because of the large quantities of precipitated salts from a large volume of bath with a high rate of production, these process wastes are identified separately in the table.

A recapitulation of the significant quantities of process and

TABLE 31. ASSUMED METAL CONCENTRATIONS IN WASTEWATER*

Metal	Concentration, mg/l
Cu	0.5
Ni	0.5
Cr	0.5
Zn	0.5
Al	1.0
Cd	0.5
Fe	1.0

* U. S. EPA - Electroplating Point Source Category. Interim Effluent Limitations and Guidelines, and Proposed Performance and Pretreatment Standards. Federal Register, Thursday, April 24, 1975, Vol. 40, No. 80, Part II.

TABLE 32. CHARACTERISTICS AND SLUDGE PRODUCTION RATES OF THE MODEL PLANTS

Number of Employees	16		38		87	
Production Rate						
Square meters per day	1,440		3,400		6,960	
Square feet per day	15,520		36,576		74,904	
Wastewater Discharge						
Liters per day	146,710		314,530		660,010	
Gallons per day	38,760		83,100		175,960	
Sludge Production Rate at 20% Solids						
Liters per day	305.6		701		1,616	
Gallons per day	80.8		185		428	
Sludge Production Rate dry weight, metal hydroxides						
Kilograms per day	60.8		140.2		324	
Pounds per day	134.4		309.2		715	
Metal Hydroxides in Sludges						
	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
$Cr(OH)_3$	19.20	42.32	34.98	77.22	78.00	172.24
$Ni(OH)_2$	6.88	15.12	11.22	24.77	49.28	108.80
$Zn(OH)_2$	4.64	10.16	13.60	30.02	19.92	44.00
$Fe(OH)_2$	3.20	7.06	14.78	32.62	28.08	62.08
$Al(OH)_3$	4.16	7.20	23.85	52.67	46.40	96.00
$Cu(OH)_2$	2.80	6.24	4.38	9.67	30.08	65.36
$Pb(OH)_2$	-	-	-	-	9.12	20.24
$Cd(OH)_2$	1.12	2.40	0.96	2.13	0.72	1.68
$Sn(OH)_2$	-	-	-	-	0.72	1.68

TABLE 33. SOLID WASTES FROM PLATING OPERATIONS OF MODEL PLANT A

Line No. and Bath	Anode Sludge		Anode Scrap		Metal Scrap[a]		Anode Bags		Filter Cake[b]		Chemicals[c]			
											Solution Components[d]		Na_2CO_3	
	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr
1) Cu	25	54	444	910	--	--	6	13	44	98	51	112	170	375
Ni	198	436	[2964]	[6536][e]	472	1000	25	55	192	423	217	478	--	--
Cr	11	25[f]	--	--	--	--	--	--	--	--	--	--	--	--
2) Cu	7	15	124	273	--	--	2	4	36	79[g]	14	31	85	188
Ni	55	122	--	--	94	200	1	2	54	119	55	121	--	--
Cr	3	6	--	--	--	--	--	--	--	--	--	--	--	--
3) Zn	113	249	565	1245	204	450[h]	--	--	15	33	15	33	766	1690
4) Zn	68	150	339	747	122	270[h]	--	--	9	20	9	20	460	1014
5) Cd	40	88	201	444	18	40	--	--	4	8	4	8	170	375
6) Cr	1	2	--	--	--	--	--	--	--	--	--	--	--	--
7) Anodizing	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8) Phosphating	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9) Electroless Ni	--	--	--	--	--	--	--	--	209	460	--	--	14,984	33,040[i]
Totals	521	1147	1673	3689	911	1960	34	74	354	780	364	803	1,651 14,984[i]	3,642 33,040[i]

a) Scrap generated by electrolytic bath purification composed of metallic impurities and metal-bath constituent.
b) Composed of 83 percent diatomaceous earth and 17 percent activated carbon.
c) Based on a 50-week year.
d) Quantity of chemicals absorbed in filter cakes and anode bags in concentrations of the bath constituents.
e) Scrap anodes are reused in Ni-bath of Line 2.
f) Composed of Pb, Sb, and CrO_3.
g) 24 kg (52 lb) are discarded filter cartridges.
h) Composed of zinc polysulfides and metallic impurities generated during chemical-bath purification.
i) Calcium orthophosphite and calcium sulfate precipitated during bath regeneration.

TABLE 34. MISCELLANEOUS WASTES FROM OPERATION OF MODEL PLANT A

Waste Source	Type of Waste	Amount of Waste		Mode of Disposal	Additional Manpower
		kg/yr	lb/yr[a]		
Polishing and Buffing					12
Metal removal (brass)	Solid	3,040	6,710	Landfill	
Compound[b]	Sludge	12,607	27,830	Landfill	
Wheels and buffs	Solid	3,040	6,710	Landfill	
		3,040	6,710	Used buffs to supplier	
Deburring					1
Metal removal	Wet	730	1,615	Discharged to sewer in small quantities, lost in production	
Aluminum oxide	Wet	730	1,615		
Proprietary compound	Solid	7,550	16,440		
Steel balls and shapes	Wet	945	12,080		
Grinding and Sizing[c]	Solid	2,060	4,550	Landfill	1
Chromium	Solid	380	840	To scrap dealer	
Rejects					
Steel	Solid	37,640	83,000	To scrap dealer	
Brass	Solid	2,330	5,130	To scrap dealer	
Plating Racks					1
Coating	Solid	1,615	3,560	Landfill	
Ti-rack tips	Solid	810	1,780	To scrap dealer	
Racks (brass)	Solid	1,610	3,550	To scrap dealer	
Contact buildup[d]					
Cu	Solid	160	350		
Ni	Solid	1,270	2,800		
Zn	Solid	950	2,100	To scrap dealer	
Cl	Solid	160	355		
Cr	Solid	60	135		
Degreaser[b]					0
$CHCl:CCl_2$	Sludge	2,054	4,530	Landfill	

a) Based on a 250-day year.

b) Polishing and buffing compounds are dissolved in $CHCl:CCl_2$, forming a sludge which is periodically removed.

c) Preparation and finishing of hard chromium plating of ferrous alloys.

d) From periodic cleaning of racks.

solid wastes are given in Table 35. In this table, the various waste quantities are all expressed as dry weight or as solid materials.

Survey Data

An analysis of the 88 written responses to this study from the job shops indicated that 57 facilities generate some form of waste. Seventeen of the responses stated that no wastes were disposed of by landfill, while 14 responses gave no information whatsoever.

The types and characteristics of wastes reported by industry are tabulated in Appendix E. Of the 90 wastes identified by the respondents, 26 were clearly identified as water pollution control sludges, 14 as resulting from air pollution control, 23 as wastes associated with plating operations, 26 as coming from other categories of operations, and one was not identified as to the source or type. Indications of composition were given in 26 of the 90 wastes. These data serve to illustrate the variability of the wastes, in accord with the previously discussed latitutde of process operations characteristic of the electroplating and metal finishing industry.

Those company code numbers containing the "IPC" (Institute of Printed Circuits) designation exhibit, in general, tendencies to show copper, lead, tin, epoxy, and fiberglas in their wastes, associated with the processing of circuit boards with copper-solder materials. The balance of the wastes show a common occurrence of copper, nickel, chromium, and zinc. Cyanide, lead, and cadmium are also reported in some of the wastes. Quantities of waste are also highly variable. Efforts to aggregate or sum the reported waste quantities are in many cases voided by the absence of one or more factors, e.g., wet or dry basis, solids content, plant operating schedules, etc.

In view of the small fraction of plants reporting and the highly variable nature of the wastes, these data were judged insufficient as a basis for the projection of wastes, particularly on a state-by-state basis. The data supplied by industry serves as a basis for the understanding of the qualifications which apply to any model plant developed for the industry.

Current Potentially Hazardous Waste (1975)

The data developed on the waste generation factors from the model plants and the state and regional distribution of job shops as given in Section I on Industry Characterization (Table 2) were used to calculate the quantity of total industry and potentially hazardous wastes destined for land disposal. Plants having only 1 to 5 employees were eliminated because of their exemption from effluent limitations.

The numbers of facilities in a given state were aggregated into three size ranges corresponding to the model plants, and are given in Table 36 by state, EPA region, and nationally. The waste generation rates of each of the model plants were then multiplied by the number of plants

TABLE 35. SUMMARY OF WASTE QUANTITIES DERIVED FROM MODEL PLANTS [(a)]

	Plant Size (Employees)					
	16		38		87	
	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr
Water treatment sludge[(b)]	15,200	33,600	35,000	77,140	81,000	178,750
Process wastes[(c)]	12,110	26,710	25,310	55,810	58,580	129,160
Degreaser sludge[(d)]	2,050	4,530	3,590	7,920	4,210	9,290
Total	29,300	64,840	63,900	140,870	143,790	317,200
Electroless Nickel wastes	None	None	14,625	32,235	14,625	32,235
TOTAL	29,300	64,840	78,525	173,105	158,415	349,435

a) All estimates are for a 250 working day year.

b) Dry weight of metal hydroxides and precipitates from process solutions.

c) Includes solid materials generated during the metal finishing operations and allows for occluded chemicals (dry weight).

d) Amount of trichloroethylene lost as sludge from degreaser operations.

TABLE 36. DISTRIBUTION AND NUMBER OF ELECTROPLATING AND METAL FINISHING JOB SHOPS USED IN ESTIMATION OF SOLID WASTE GENERATION

	Plant Size (No. of Employees)			
EPA Region and State	16	38*	87	Total
Region I				
Massachusetts	56	31	6	93
Connecticut	58	25	11	94
Rhode Island	0	71	6	77
New Hampshire	3	0	0	3
Maine	2	0	1	3
Vermont	2	1	0	3
Region I Total	121	128	24	273
Region II				
New Jersey	85	21	6	112
New York	98	45	21	164
Region II Total	183	66	27	276
Region III				
Delaware	1	0	0	1
Maryland	11	2	0	13
Pennsylvania	69	23	11	103
Virginia	0	2	1	3
West Virginia	8	4	2	14
Region III Total	89	31	14	134
Region IV				
Alabama	14	6	1	21
Florida	26	5	1	32
Georgia	6	2	3	11
Kentucky	4	5	2	11
Mississippi	7	0	1	8
North Carolina	11	8	2	21
South Carolina	8	1	2	11
Tennessee	8	10	2	20
Region IV Total	84	37	14	135
Region V				
Illinois	110	36	24	170
Indiana	47	13	9	69
Michigan	123	101	33	257
Minnesota	18	9	4	31
Ohio	144	46	22	212
Wisconsin	20	8	6	34
Region V Total	462	213	98	773

* Includes those for which the number of employees is not known.

TABLE 36. (CONTINUED)

EPA Region and State	Plant Size (No. of Employees) 16	38*	87	Total
Region VI				
Arkansas	2	2	1	5
Louisiana	1	1	0	2
New Mexico	5	1	0	6
Oklahoma	7	1	2	10
Texas	46	14	8	68
Region VI Total	61	19	11	91
Region VII				
Iowa	15	3	4	22
Kansas	14	0	7	21
Missouri	30	6	9	45
Nebraska	3	2	0	5
Region VII Total	62	11	20	93
Region VIII				
Colorado	14	3	5	22
Montana	1	0	0	1
North Dakota	0	0	0	0
South Dakota	1	0	0	1
Utah	6	1	0	7
Wyoming	0	0	0	0
Region VIII Total	22	4	5	31
Region IX				
Arizona	11	4	1	16
California	80	34	15	129
Hawaii	1	0	0	1
Nevada	4	0	0	4
Region IX Total	96	38	16	150
Region X				
Alaska	0	0	0	0
Idaho	3	0	0	3
Oregon	10	1	3	14
Washington	20	4	0	24
Region X Total	33	5	3	41
Total U. S.	1,213	552	232	1,997

* Includes those for which the number of employees is not known.

in each size range for each of the states.

The waste generation factors of the model plants are based on the U.S. EPA effluent limitations and guidelines*, which are to apply in 1977 and 1983 and on the total production. To establish quantities for 1975, various factors had to be taken into consideration. The adjustment of the basic 1977 model plant waste quantities to 1975 waste generation levels involves an allowance for the number of plants that are not currently producing water pollution control sludges. To estimate this situation, information was gathered from state and local agencies to determine what degree or what incidence of pollution control currently exists. These estimates were greatly influenced by local conditions. As an example, platers in New York City are not required to treat before discharge, while Chicago has existing regulations equivalent to the proposed Federal effluent limitations. Such estimates were developed to the best degree possible for areas (states) containing the larger numbers of electroplating job shops. A review of the 88 industry responses accordingly showed that about 35 percent of the reporting plants produced water pollution control sludge in 1975. Of those 88, only small changes in sludge volume or composition were expected for 1977 because of increased production or changes in water pollution control equipment. Despite the viewpoint expressed by these respondents, it was assumed that the Effluent Limitation Guidelines will become effective and that most electroplating and metal finishing facilities will install water pollution control systems on schedule.

Thus, it is concluded that the significant differences in waste quantities between 1977 and 1975 will be in the water pollution control sludge quantities. Economic conditions in general and data from Figure 1 (see Section I, p. 4) would indicate that the industry will not undergo any major expansion or reduction. Consequently, the wastes generated from electroplating and metal finishing processes other than water pollution control sludges will remain unchanged between 1975 and 1977.

Table 37 shows the estimated quantities of the four categories of waste and of total industry and potentially hazardous wastes destined for land disposal by the electroplating and metal finishing job shops in metric tons per year for each state, EPA Region, and nationally. The total industry and the potentially hazardous wastes for 1975 is estimated to be 78,740 metric tons (dry weight). The major portion of the wastes, 54 percent, are process wastes as indicated in Table 37. The water pollution control sludges account for 25 percent of the total, followed by electroless nickel plating wastes, 15 percent, and 6 percent for degreaser sludges. The fact that only an estimated 35 percent of the total job shops are producing water pollution control sludges in 1975 is the main reason that the general process wastes associated with all electroplating and metal finishing operations account for more than half of the total wastes.

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* U.S. EPA - Electroplating Point Source Category. Interim Effluent Limitations and Guidelines, and Proposed Performance and Pretreatment Standards. Federal Register, Thursday, April 24, 1975, Vol. 40, No. 80, Part II.

TABLE 37. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*, 1975

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total
Region I					
Massachusetts	847.77	1,814.25	251.35	541.13	3,454.50
Connecticut	926.66	1,979.51	254.96	526.50	3,687.63
Rhode Island	1,039.85	2,148.49	280.15	1,126.13	4,594.62
New Hampshire	15.96	36.33	6.15	0.00	58.44
Maine	38.99	82.80	8.31	14.63	144.73
Vermont	22.89	49.53	7.69	14.63	94.73
Region I Total	2,892.12	6,110.91	808.61	2,223.02	12,034.65
Region II					
New Jersey	879.55	1,912.34	274.90	394.88	3,461.67
New York	1,667.96	3,555.91	450.86	965.25	6,639.98
Region II Total	2,547.51	5,468.25	725.76	1,360.13	10,101.65
Region III					
Delaware	5.32	12.11	2.05	0.00	19.48
Maryland	83.02	183.83	29.73	29.25	325.83
Pennsylvania	960.68	2,062.10	270.33	497.25	3,790.36
Virginia	52.85	109.20	11.39	43.88	217.32
West Virginia	148.26	315.28	39.18	87.75	590.47
Region III Total	1,250.13	2,682.52	352.68	658.13	4,943.46
Region IV					
Alabama	176.33	379.98	54.45	102.38	713.14
Florida	203.42	449.37	68.28	58.50	779.57
Georgia	141.47	299.02	32.11	73.13	545.73
Kentucky	139.23	292.15	34.57	102.38	568.33
Mississippi	65.59	143.35	18.56	14.63	242.13
North Carolina	213.22	452.85	59.69	146.25	872.01
South Carolina	111.51	239.35	28.41	43.88	423.15
Tennessee	193.41	408.56	56.51	160.88	819.36
Region IV Total	1,297.03	2,773.83	363.97	745.88	4,963.42
Region V					
Illinois	1,706.60	3,649.18	455.78	877.50	6,689.06
Indiana	664.44	1,425.42	180.91	321.75	2,592.52
Michigan	2,827.16	5,978.98	753.67	1,959.75	11,519.56
Minnesota	319.41	680.09	86.05	190.13	1,275.68
Ohio	1,953.28	4,196.86	552.96	994.50	7,697.60
Wisconsin	374.50	796.16	94.98	204.75	1,470.39
Region V Total	7,845.39	16,726.69	2,124.35	4,548.38	31,244.81

* These dry weights can be converted to wet weights by applying the following factors: WPCS - 20; PW - 1; DS - 1; ENiW = 2.

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE 37. (Continued)

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total
Region VI					
Arkansas	63.49	133.42	15.49	43.88	256.28
Louisiana	17.57	37.42	5.64	14.63	75.25
New Mexico	38.85	85.86	13.84	14.63	153.18
Oklahoma	106.19	227.24	26.36	43.88	403.67
Texas	643.02	1,380.04	178.24	321.75	2,523.05
Region VI Total	869.12	1,863.98	239.57	438.75	3,411.43
Region VII					
Iowa	229.95	491.90	58.36	102.38	882.58
Kansas	272.93	579.60	58.17	102.38	1,013.08
Missouri	488.25	1,042.38	120.93	219.38	1,870.94
Nebraska	40.46	86.95	13.33	29.25	169.99
Region VII Total	1,031.59	2,200.83	250.79	453.38	3,936.59
Region VIII					
Colorado	252.98	538.37	60.52	117.00	968.87
Montana	5.32	12.11	2.05	0.00	19.48
North Dakota	0.00	0.00	0.00	0.00	0.00
South Dakota	5.32	12.11	2.05	0.00	19.48
Utah	44.17	97.97	15.89	14.63	172.66
Wyoming	0.00	0.00	0.00	0.00	0.00
Region VIII Total	307.79	660.56	80.51	131.63	1,180.49
Region IX					
Arizona	135.87	293.03	41.12	73.13	543.15
California	1,267.35	2,708.04	349.21	716.63	5,041.23
Hawaii	5.32	12.11	2.05	0.00	19.48
Nevada	21.28	48.44	8.20	0.00	77.92
Region IX Total	1,429.82	3,061.62	400.58	789.75	5,681.78
Region X					
Alaska	0.00	0.00	0.00	0.00	0.00
Idaho	15.96	36.33	6.15	0.00	58.44
Oregon	150.50	322.15	36.72	58.50	567.87
Washington	155.40	343.44	55.36	58.50	612.70
Region X Total	321.86	701.92	98.23	117.00	1,239.01
Total U. S.	19,792.39	42,251.18	5,445.06	11,466.00	73,737.29

Additional data pertinent to these wastes are included in Appendix E. These data in Table E-1 indicate that 40 percent of this amount will derive from plants with from 26 to 50 employees, as represented by the medium size plant. The larger plants with more than 50 employees will produce 30 percent of the total waste, as will the large number of the small plants employing between 5 and 25 people.

The tabulated data in Appendix E also identify the respective quantities of water pollution control sludges, process wastes, degreaser sludges, and electroless nickel plating wastes destined for land disposal by the job shops falling under the grouping of small, medium, and large model plants, respectively.

Table E-6 indicates the quantity of metal constituents from the water pollution control sludges disposed of by landfill as their respective hydroxide by state, EPA Region, and nationally in 1975, listed in decreasing order.

The land disposal distribution by small, medium, and large job shops by state, EPA Region, and nationally for each individual metal has been calculated and is given in Table E-7 through E-16.

Potentially Hazardous Wastes for 1977 and 1983

As discussed previously, the waste treatment processes for the model plants was developed according to the 1977 EPA effluent limitations and guidelines requiring pretreatment of the plant effluents. Consequently, the quantity of the water pollution control sludges was obtained by multiplying the waste generation factors of the small, medium, and large model plants by the respective number of plants in each state. Process wastes, degreaser sludges, and electroless nickel wastes were also calculated from the waste data of the model plants, again through multiplication by the number of plants in each area.

The calculated quantity of total industry and potentially hazardous waste destined for land disposal by the electroplating and metal finishing job shops in metric tons per year in 1977 are given in Table 38. The 115,390 metric tons (dry weight) represent an increase of almost 50 percent over the 1975 waste quantities, all of it coming from the additional load of the water pollution control sludge, as shown by Table 39. Forty-nine percent of the 1977 total waste is water pollution control sludge. The process wastes account for almost 37 percent, electroless nickel wastes and degreaser sludge constitute 10 and 4 percent of the waste, respectively. The concurring distribution in 1975 is 25-54-15-6 percent.

Additional information regarding the characteristics of these wastes generated in 1977 also is contained in Appendix E in Tables E-17 through E-32.

TABLE 38. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1977

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total
Region I					
Massachusetts	2,422.20	1,814.25	251.35	541.13	5,028.93
Connecticut	2,647.60	1,979.51	254.96	526.50	5,408.57
Rhode Island	2,971.00	2,148.49	280.15	1,126.13	6,525.77
New Hampshire	45.60	36.33	6.15	0.00	88.08
Maine	111.40	82.80	8.31	14.63	217.14
Vermont	65.40	49.53	7.69	14.63	137.25
Region I Total	8,263.20	6,110.91	808.61	2,223.02	17,405.74
Region II					
New Jersey	2,513.00	1,912.34	274.90	394.88	5,095.12
New York	4,765.60	3,555.91	450.86	965.25	9,737.62
Region II Total	7,278.60	5,458.25	725.76	1,360.13	14,832.74
Region III					
Delaware	15.20	12.11	2.05	0.00	29.36
Maryland	237.20	183.83	29.73	29.25	480.01
Pennsylvania	2,744.80	2,062.10	270.33	497.25	5,574.48
Virginia	151.00	109.20	11.39	43.88	315.47
West Virginia	423.60	315.28	39.18	87.75	865.81
Region III Total	3,571.80	2,682.52	352.68	658.13	7,265.13
Region IV					
Alabama	503.80	379.98	54.45	102.38	1,040.61
Florida	581.20	449.37	68.28	58.50	1,157.35
Georgia	404.20	299.02	32.11	73.13	808.45
Kentucky	397.80	292.15	34.57	102.38	826.90
Mississippi	187.40	143.35	18.56	14.63	363.94
North Carolina	609.20	452.85	59.69	146.25	1,267.99
South Carolina	318.60	239.35	28.41	43.88	630.24
Tennessee	552.60	408.56	56.51	160.88	1,178.55
Region IV Total	3,554.80	2,664.63	352.58	702.03	7,274.04
Region V					
Illinois	4,876.00	3,649.18	455.78	877.50	9,858.46
Indiana	1,898.40	1,425.42	180.91	321.75	3,826.48
Michigan	8,077.60	5,978.98	753.67	1,959.75	16,770.00
Minnesota	912.60	680.09	86.05	190.13	1,868.87
Ohio	5,580.80	4,196.86	552.96	994.50	11,325.12
Wisconsin	1,070.00	796.16	94.9[illegible]	204.75	2,165.89
Region V Total	22,415.40	16,726.69	2,124.3[illegible]	4,548.38	45,814.82

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* These dry weights can be converted to wet weights by applying the following factors: WPCS - 5; PW - 1; DS - 1; ENiW - 2.

Note: Total Industry Waste = Potentially Hazardous Wastes

TABLE 38. (Continued)

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total
Region VI					
Arkansas	181.40	133.42	15.49	43.88	374.19
Louisiana	50.20	37.42	5.64	14.63	107.89
New Mexico	111.00	85.86	13.84	14.63	225.33
Oklahoma	303.40	227.24	26.36	43.88	600.88
Texas	1,837.20	1,380.04	178.24	321.75	3,717.23
Region VI Total	2,483.20	1,863.98	239.57	438.77	5,025.52
Region VII					
Iowa	657.00	491.90	58.36	102.38	1,309.64
Kansas	779.80	579.60	58.17	102.38	1,519.95
Missouri	1,395.00	1,042.38	120.93	219.38	2,777.69
Nebraska	115.60	86.95	13.33	29.25	245.13
Region VII Total	2,947.40	2,200.83	250.79	453.39	5,852.41
Region VIII					
Colorado	722.80	538.37	60.52	117.00	1,438.69
Montana	15.20	12.11	2.05	0.00	29.36
North Dakota	0.00	0.00	0.00	0.00	0.00
South Dakota	15.20	12.11	2.05	0.00	29.36
Utah	126.20	97.97	15.89	14.63	254.69
Wyoming	0.00	0.00	0.00	0.00	0.00
Region VIII Total	879.40	660.56	80.51	131.63	1,752.10
Region IX					
Arizona	388.20	293.03	41.12	73.13	795.48
California	3,621.00	2,708.04	349.21	716.63	7,394.88
Hawaii	15.20	12.11	2.05	0.00	29.36
Nevada	60.80	48.44	8.20	0.00	117.44
Region IX Total	4,085.20	3,061.62	400.58	789.76	8,337.16
Region X					
Alaska	0.00	0.00	0.00	0.00	0.00
Idaho	45.60	36.33	6.15	0.00	88.08
Oregon	430.00	322.15	36.72	58.50	847.37
Washington	444.00	343.44	55.36	58.50	901.30
Region X Total	919.60	701.92	98.23	117.00	1,836.75
Total U. S.	56,398.60	42,131.91	5,433.66	11,422.24	115,386.41

TABLE 39. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1983

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total
Region I					
Massachusetts	3,173.08	2,376.67	329.27	708.87	6,587.89
Connecticut	3,468.36	2,593.16	334.00	689.72	7,085.23
Rhode Island	3,892.01	2,814.52	367.00	1,475.22	8,548.75
New Hampshire	59.74	47.59	8.06	0.00	115.38
Maine	145.93	108.47	10.89	19.16	284.45
Vermont	85.67	64.88	10.07	19.16	179.79
Region I Total	10,824.79	8,005.29	1,059.28	2,912.13	22,801.49
Region II					
New Jersey	3,292.03	2,505.17	360.12	517.29	6,674.60
New York	6,242.94	4,658.24	590.63	1,364.48	12,756.28
Region II Total	9,534.97	7,163.41	950.75	1,781.76	19,430.88
Region III					
Delaware	19.91	15.86	2.69	0.00	38.46
Maryland	310.73	240.82	38.95	38.32	628.81
Pennsylvania	3,595.69	2,701.35	354.13	651.40	7,302.57
Virginia	197.81	143.05	14.92	57.48	413.26
West Virginia	554.92	413.02	51.33	114.95	1,134.21
Region III Total	4,679.06	3,514.10	462.01	862.14	9,517.31
Region IV					
Alabama	659.98	497.77	71.33	134.11	1,363.19
Florida	761.37	588.67	89.45	76.64	1,516.13
Georgia	529.50	391.72	42.06	95.79	1,056.08
Kentucky	521.12	382.72	45.29	134.11	1,083.23
Mississippi	245.49	187.79	24.31	19.16	476.75
North Carolina	798.05	593.23	78.19	191.59	1,661.07
South Carolina	417.37	313.55	37.22	57.48	825.61
Tennessee	723.91	535.21	74.03	210.75	1,543.89
Region IV Total	4,854.60	3,633.72	476.80	977.10	9,942.21
Region V					
Illinois	6,387.56	4,780.43	597.07	1,149.53	12,914.58
Indiana	2,486.90	1,867.30	236.99	421.49	5,012.69
Michigan	10,581.66	7,832.46	987.31	2,567.27	21,968.70
Minnesota	1,195.51	890.92	112.73	249.06	2,448.21
Ohio	7,310.85	5,497.89	724.38	1,302.80	14,835.91
Wisconsin	1,401.70	1,042.97	124.42	268.22	2,837.32
Region V Total	29,364.17	21,911.96	2,782.90	5,958.37	60,017.41

* These dry weights can be converted to wet weights by applying the following factors: WPCS - 5; PW - 1; DS - 1; ENiW - 2.

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE 39. (Continued)

EPA Region and State	Water Pollution Control Sludges	Process Wastes	Degreaser Sludges	Electroless Ni Wastes	Total
Region VI					
Arkansas	237.63	174.78	20.29	57.48	490.18
Louisiana	65.76	49.02	7.39	19.16	141.33
New Mexico	145.41	112.48	18.13	19.16	295.18
Oklahoma	397.45	297.68	34.53	57.48	787.15
Texas	2,406.73	1,807.85	233.49	421.49	4,869.57
Region VI Total	3,252.99	2,441.81	313.84	574.76	6,583.41
Region VII					
Iowa	860.67	644.39	76.45	134.11	1,715.62
Kansas	1,021.54	759.28	76.20	134.11	1,991.13
Missouri	1,827.45	1,365.52	158.42	287.38	3,638.77
Nebraska	151.44	113.90	17.46	38.32	321.12
Region VII Total	3,861.09	2,883.09	328.53	593.92	7,666.64
Region VIII					
Colorado	946.87	705.26	79.28	153.27	1,884.68
Montana	19.91	15.86	2.69	0.00	38.46
North Dakota	0.00	0.00	0.00	0.00	0.00
South Dakota	19.91	15.86	2.69	0.00	38.46
Utah	165.32	128.34	20.82	19.16	333.64
Wyoming	0.00	0.00	0.00	0.00	0.00
Region VIII Total	1,152.01	865.33	105.47	172.43	2,295.24
Region IX					
Arizona	508.54	383.87	53.87	95.79	1,042.07
California	4,743.51	3,547.53	457.47	938.78	9,687.29
Hawaii	19.91	15.86	2.69	0.00	38.46
Nevada	79.65	63.46	10.74	0.00	153.85
Region IX Total	5,351.61	4,010.72	524.76	1,034.57	10,921.67
Region X					
Alaska	0.00	0.00	0.00	0.00	0.00
Idaho	59.74	47.59	8.06	0.00	115.38
Oregon	563.30	422.02	48.10	76.64	1,110.05
Washington	581.64	449.91	72.52	76.64	1,180.70
Region X Total	1,204.68	919.52	128.68	153.27	2,406.14
Total U. S.	74,080.10	55,349.05	7,133.03	15,020.46	151,582.40

Waste projections for 1983 are based strictly on a study performed for the U.S. EPA Effluent Guidelines Division*, since the responses obtained from the 88 job shops do not project to 1983, naming the proposed 1983 zero discharge limitation of plant effluents as the reason for the inability to determine or predict water pollution control sludge loads. Necessary changes in treatment practices are another reason given. The above cited report also projects an industry growth of 31 percent from 1977 to 1983. Consequently, the quantities of total industry and potentially hazardous wastes in 1983 were calculated by multiplying the 1977 quantities estimated by a factor of 1.31. The quantity of waste by state, EPA Region, and nationally are summarized in Table 39 for the four designated waste categories. The total estimated quantity of waste destined for land disposal in 1983 is 151,583 metric tons dry weight. The 38-employee model plant (or medium sized job shop) represents the group of plants with the greatest waste load. Water pollution control sludges are the most important contributors to that waste load containing large quantities of hazardous metal hydroxides and soluble salts.

Tables E-33 through E-48 of Appendix E contain additional data for the projected potentially hazardous wastes for the industry in 1983.

A summary of all the wastes destined for land disposal by the electroplating and metal finishing job shop industry for 1975, 1977, and 1983 is given in Tables 40 and 41 for comparing waste loads and ratios of waste categories from the job shops represented by one of these model plants:

Small with an average of 16 employees in plating.

Medium with an average of 38 employees in plating.

Large with an average of 87 employees in plating.

It is estimated that 40 percent of all the potentially hazardous wastes from the electroplating and metal finishing industry will be produced by plants located in EPA Region V for the 3 years under discussion (1975, 1977, and 1983). Further, more than two-thirds of these wastes will be produced in EPA Regions I, II, and V.

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* Economic Analysis of Effluent Guidelines - Metal Finishing Industry, Report No. EPA 230/1-74-032, Sept. 1974, p. VI-8.

TABLE 40. TOTAL ESTIMATED HAZARDOUS WASTES FROM ELECTROPLATING AND METAL FINISHING JOB SHOPS, METRIC TONS, DRY WEIGHT (50 Week Year)

		Model Plants			Waste Categories					
		Small(1)	Medium(2)	Large(3)	Water Pollution Control Sludge (WPCS)	Process Wastes (PW)	Degreaser Sludge (DS)	Subtotal(4)	Electroless Nickel Waste (ENW)	Total
	Employees	16	38	87						
Year	No. of Plants	1213	552	232						
1975		23,629.36	30,787.80	24,537.48	19,792.39	42,251.18	5,445.06	67,488.63	11,466.00	78,954.64
1977		35,613.86	43,345.80	36,752.28	56,549.69	42,251.18	5,445.06	104,245.93	11,466.00	115,711.94
1983		46,654.15	56,783.00	48,145.49	74,080.10	55,349.05	7,133.03	136,562.18	15,020.46	151,582.64

(1) Representative of 1213 job shops with from 5 to 25 employees in plating and a production of 1440 m^2/day.
(2) Representative of 552 job shops with from 26 to 50 employees in plating and a production of 3400 m^2/day.
(3) Representative of 232 job shops with more than 50 employees in plating and a production of 6960 m^2/day.
(4) Combined WPCS, PW, and DS wastes.

TABLE 41. TOTAL ESTIMATED HAZARDOUS WASTES FROM 1977 ELECTROPLATING AND METAL FINISHING JOB SHOPS, METRIC TONS, DRY WEIGHT (50 Week Year)

		Model Plant			
Waste Category	Year	Small(1)	Medium(2)	Large(3)	Total
Water Pollution Control Sludge	1975	6,453.19	6,762.00	6,577.20	19,792.39
	1977	18,437.60	19,320.00	18,792.00	56,549.60
	1983	24,153.38	25,309.20	24,617.52	72,080.10
Process Wastes	1975 & 1977	14,689.50	13,971.12	13,590.56	42,251.18
	1983	19,243.25	18,302.17	17,803.63	55,349.05
Degreaser Sludge	1975 & 1977	2,486.66	1,981.68	976.72	5,445.06
	1983	3,257.53	2,596.00	1,279.50	7,133.03
Electroless Nickel Waste	1975 & 1977	0.00	8,073.00	3,393.00	11,466.00
	1983	0.00	10,575.63	4,444.83	15,020.46

(1) Representative of 1213 job shops with from 5 to 25 employees in plating and a production of 1440 m^2/day.

(2) Representative of 552 job shops with from 26 to 50 employees in plating and a production of 3400 m^2/day.

(3) Representative of 232 job shops with more than 50 employees in plating and a production of 6960 m^2/day.

REFERENCES
WASTE CHARACTERIZATION

(1) "Electroplating Engineering Handbook, Edited by A. Kenneth Graham, 3rd Edition, 1971, Van Nostrand Reinhold Company, New York.

(2) "Modern Electroplating", Edited by F. A. Lowenheim, John Wiley and Sons, Inc., New York, 1974.

(3) "Metals Handbook", Eighth Edition, Vol. 2, Edited by L. Taylor, American Society for Metals, Metals Park, Ohio, 1964.

(4) "Metal Finishing Guidebook and Directory", Metal and Plastics Publications, Inc., Hackensack, New Jersey, 1975.

(5) "Plating Chemical Recovery Units for Chrome and Nickel", Corning Glass Works, Corning, New York, 1974.

(6) "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards, Copper, Nickel, Chromium, and Zinc Segment of the Electroplating Point Source Category", U.S. Environmental Protection Agency, EPA-440/1-73-003, August, 1973.

(7) "Metal Finishing Waste Treatment in Sweden", B. Goransson and P. O. Moberg, Journal of Water Pollution Control Federation, Vol. 47, No. 4, April, 1975.

III. TREATMENT AND DISPOSAL TECHNOLOGY

The objective of this phase of the study was to identify and describe the treatment and the ultimate disposal technologies employed by electroplating and metal finishing job industry shops under the Standard Industrial Classification (SIC) 3471. These operations were described in more detail in the Waste Characterization section of the report. In this section, the various treatment and/or disposal technologies and the fate of the waste materials are identified and quantified on the basis of an industry survey. Current treatment and disposal methods are also discussed and reviewed.

The methodology employed in treating the data from the industry survey and the rationale leading to the final selection of the industry sample are given. The data were tabulated and assessed to determine the present state of the art of treatment and disposal technology applied to reduce the potential hazards of disposal by the industry sample. The data were also employed to determine the use of on-site versus off-site treatment and disposal methods and the types of off-site facilities used for ultimate disposal, the quantities of wastes involved, and the identity and frequency of use of those companies that treat and/or dispose of wastes from job shops on a contract basis. The services provided by treatment and disposal contractors together with user charges, disposal methods, and safeguards employed during disposal were reviewed.

This information provided the basis for determining the three levels of treatment and/or disposal technology for those potentially hazardous wastes generated from the electroplating and metal finishing industry. The technology levels identified in this report are the technology currently employed by typical facilities (Level I), the best technology currently in use in at least one location on a commercial scale (Level II), and the technology level either in operation or being developed necessary to provide adequate health and environmental protection (Level III). Each of the technology levels has been assessed for adequacy of health and environmental protection in the framework of 14 factors set forth in the work statement.

DESCRIPTION OF WASTES DESTINED FOR LAND DISPOSAL

Although the potentially hazardous wastes destined for land disposal are described in the previous section of the report, their characteristics are summarized here for the convenience of the reader. The relationships between these wastes and other waste materials, e.g., wastewater and spent plating baths, also are discussed briefly in a subsequent subsection on treatment and disposal methods.

Water Pollution Control Sludge

When rinse waters and spent plating baths are treated in wastewater treatment plants, insoluble hydroxides of the metal constituents normally are produced. The precipitated solids are dewatered by various means to levels ranging from less than 5 to more than 20 percent of solids. The level of hazard to health and the environment in the water is reduced by cyanide oxidation, chromium reduction, and heavy metal precipitation; however, the potential hazard is transferred to the precipitates removed from solution which are now destined for land disposal. In the printed circuit job shops, the waste solutions may be etching waste solutions as well as those related to plating operations. Although municipal sewage plants usually do not accept such solutions without pretreatment, there are many instances in which the smaller job shops discharge spent baths directly to the sewer.

Process Wastes

This category of wastes includes plating sludges, waste chemicals, air pollution control dusts, and miscellaneous solid wastes. The air pollution control dusts (including dusts not otherwise specified) are generated in buffing and polishing operations, grit blasting, and grinding.

Various other wastes also are included in this category, i.e., honing oils, oils from water pollution control, anode scrap, plating racks, etc.

The printed circuit segment of the industry generates large amounts of wastes consisting primarily of scrap pieces of epoxy-fiberglass composites (other resin systems also may be used) and the dusts from cutting and boring these materials. These are sometimes collected as separate wastes, but are usually combined with the other process solid wastes and ultimately disposed of to landfill.

Degreaser Sludges

The organic solvents used for removing the grease, oils, and paint from metal parts prior to electroplating usually are reclaimed and reused. Chlorinated hydrocarbons and normal hydrocarbons are used for metal cleaning. A combination of organic chemicals is used for paint stripping. Among these are toluene, xylene, acetone, other ketones, and methylene chloride.

When these solvents are reclaimed, the impurities (oil, grease, paint pigments, etc.) are removed as a sludge which may contain both heavy metals and traces of the organic solvents. Such sludges usually are destined for disposal in a landfill although they occasionally are incinerated.

Electroless Nickel Wastes

These wastes are generated during the regeneration of electroless nickel baths. Although not specifically included as a component of the wastes produced by plants responding to inquiries made during this study, they are produced by facilities which include electroless plating operations. As pointed out previously, most of the successful regeneration operations are based on the chemical precipitation of the phosphite ion.

ACQUISITION AND ANALYSIS OF DATA

NAMF Questionnaires

The information received in the industry survey was used to help formulate a schematic of the treatment and disposal alternatives used by the electroplating and metal finishing industry for the waste types it generates, as shown in Figure 6. Although wastewater treatment and air pollution control are identified operations, they are not considered to be part of the treatment of waste destined for land disposal. However, any residual solids collected or generated during the control of water- or airborne pollutants have been included in one of the four categories of potentially hazardous wastes.

Method of Data Assembly and Analysis

Analysis of the data led to the identification of four categories of potentially hazardous wastes destined for land disposal as described in the Waste Characterization section. These are

(1) Water pollution control sludges
(2) Process wastes
(3) Degreaser sludges
(4) Electroless nickel sludges.

The selection of these categories is not meant to infer that these are the only potentially hazardous materials which are discharged from electroplating and metal finishing operations. They were selected because it is not the normally accepted practice of this industry to dispose of some of the other potentially hazardous materials to the land.

Among the materials discharged from various plants which normally do not involve land disposal are spent plating baths (concentrated inorganic solutions) and spent solvents. The methods of disposition of these materials as well as various sludges and solid wastes were identified by some of the respondents to the data acquisition efforts.

In most instances, electroless nickel and degreaser sludges were not separately identified but were included as sludges along with the water

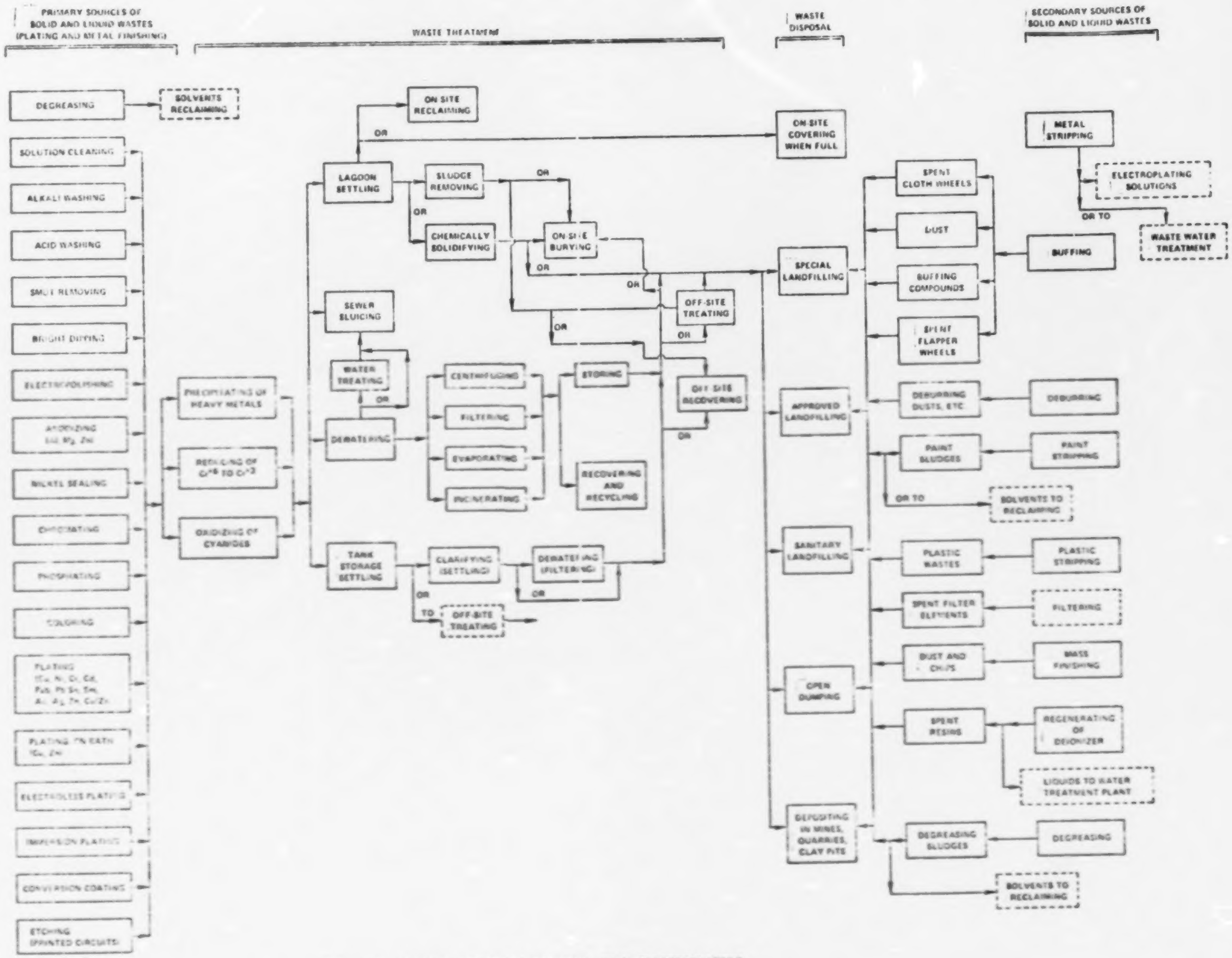

FIGURE 6. OPTIONS FOR WASTE DISPOSAL FROM ELECTROPLATING, METAL FINISHING AND PRINTED CIRCUIT INDUSTRY

pollution control sludges. Thus, only two categories of potentially hazardous wastes destined for land disposal were identified by most of the survey respondents, i.e., "sludges" and "solids". (These later were subdivided during the model plant calculations into the four distinct categories listed earlier because of the significant differences in their characteristics.)

A breakdown of the industry sample of 91 plants which is based on the analysis of the raw data is given in Table 42. Both those waste materials normally destined for land disposal and those which normally are not have been included as confirmation that further consideration should not be given in this study to the spent plating baths and organic solvents.

Results of Analysis of Industry Survey Data

Off-Site Versus On-Site Disposal. Of the 91 job shops that returned questionnaires, 50 indicated that wastes are generated for treatment and/or disposal. The remaining plants either indicated that they disposed of their wastes by dumping them in the sewer without treatment, or failed to disclose any treatment; therefore, these shops were removed from the sample population. Of the 50 plants making up the sample, 17 (or 34 percent) disposed of their treated sludges (water pollution control sludge, etc.) on site, while 33 (or 66 percent) disposed of the treated sludges off site.

Of the 50 plants, 27 reported disposal of process solid waste such as dusts, 8 plants (or 30 percent) reported disposal on site, and 19 plants (or 70 percent) reported disposal off site. These data are presented in Table 43.

Although these data indicate that one plant disposed of spent organic solvents to a special landfill, and two plants used landfills to dispose of concentrated inorganic solutions. these cases were assumed to be special exceptions to the accepted practice of the industry. (In one instance disposal was to a deep mine which certainly is a special case!) The normal practice--on the basis of this small sample and discussions with individual plant operators--is reclamation of both the solvents and the metals or discharge of the concentrated inorganic solution to the water pollution control circuit. Because it is not normal practice to dispose of these materials to the land, no further discussion will be included in this report of their potential hazardous nature.

Safeguards Used in Disposal

The treatment and disposal of potentially hazardous wastes generated by the electroplating and metal finishing industry destined for land disposal have associated dangers of ground or surface water contamination by toxic materials. To minimize these dangers, many land disposal sites have incorporated such safeguard measures as liquid-solid waste mixing prior to disposal, compaction, daily cover, clay or plastic linings, installation of monitoring wells, etc. In addition to these measures, certain

TABLE 42. BREAKDOWN OF REPORTING JOB SHOPS BASED ON THE METHOD OF DATA ASSEMBLY AND ANALYSIS OF HEAVY METAL POLLUTANT HANDLING

Type of Material Discharged	Treatment and/or Disposal Method[a]							
	No Treatment (Sewer)		Treated On-Site			Treated Off-Site		
	Acknowledged	Assumed	Landfill	Reclaimed	Fate Unknown	Landfill	Reclaimed	Fate Unknown
All Metal-Containing Wastes	27	14						
Sludges			8	-	9	13	6	14
Process Wastes			1	-	7	10	-	9
Inorganic Liquids			1	2	3	1	13	5
Organic Liquids			-	6	-	1	9	-

(a) On the basis of 91 usable responses.

TABLE 43. A COMPARISON OF ON-SITE VERSUS OFF-SITE TREATMENT AND DISPOSAL PRACTICES EMPLOYED BY THE ELECTROPLATING AND METAL FINISHING INDUSTRY

		Number of Plants Disposing[a]			
Waste Type	Total	On-Site	(Percent)	Off-Site	(Percent)
Sludges	50	17	(34)	33	(66)
Process Wastes	27	8	(30)	19	(76)

(a) More detailed information, such as the mode of disposal and the fate of materials which may be reclaimed, is presented in Table 42.

additional safeguards could be incorporated into current hazardous waste land disposal operations. In order to better characterize the current electroplating and metal finishing waste disposal practices, and assess the environmental adequacy of these practices, the usage of special safeguards employed in the disposal of potentially hazardous wastes was analyzed in terms of number of locations identified and percentage of total wastes disposed. Five special land disposal safeguards were included in this analysis:

(1) Plastic or concrete encapsulation
(2) Steel drum storage and disposal
(3) Leachate collection and treatment
(4) Chemical fixation/solidification
(5) Waste inventory, segregation, and mapping.

Plastic or Concrete Encapsulation

The encapsulation of potentially hazardous wastes in plastic or concrete is a special disposal safeguard currently being employed for only the most hazardous wastes, e.g., nerve gas, biological warfare agents, radioactive wastes, etc. Plastic encapsulation is accomplished in two phases: first, a plastic material is employed to encase the waste and secure it from escaping into the environment; and second, a steel section is employed to provide support and maintain the structural integrity of the disposal unit. Concrete encapsulation is similar, except the concrete provides both the waste encasement and the structural support. Normally, a hollow concrete chamber (often lined with stainless steel) is filled with the hazardous waste (either loose or containerized) and then concrete is poured in to cap and seal the chamber. Concrete encapsulation is predominantly employed in radioactive waste disposal since the concrete serves the dual purpose of liquid and solid waste and radiation confinement.

Analysis of the available data of plating wastes has shown that this safeguard is not employed in the industry. One atypical waste disposal contractor was identified who employs concrete encapsulation for the disposal of small quantities of plating wastes so that the waste is isolated from the environment. (The contractor is considered atypical because he employs abandoned concrete missile silos as his disposal cells.) An approximate estimate of the percentage of the total quantity of plating waste disposed of with special land disposal safeguards is summarized in Table 44. For encapsulation this quantity has been estimated to be less than 1 percent.

Steel Drum Burial

The containerization of potentially hazardous wastes in steel drums prior to disposal is another safeguard employed. Both plastic lined and unlined drums and barrels are used. Drum burial procedure usually entails (1) filling the drum with the potentially hazardous waste, (2) sealing the drum, (3) transporting the drums to the disposal site, and (4) land storage or land burial.

TABLE 44. SAFEGUARDS USED AND THE PERCENTAGE OF WASTE DISPOSED OF FROM THE METAL FINISHING INDUSTRY

Safeguard	Number of Sites Identified Employing Safeguard	Estimation of Percent of Total Waste Disposed of With Safeguards for the Electroplating and Metal Finishing Industry[(a)]
Plastic or Concrete Encapsulation	1	<1
Drum Burial	3	<4
Leachate Collection and Treatment	1	<1
Chemical Fixation/ Solidification	3	≤3
Waste Inventorying and Mapping	0	negligible
Total		<9

(a) Estimates based on the percentage of plants, rather than the actual quantities, employing the noted safeguards. The estimate was derived as (1) the percent of plants disposing on-site which employ the specific safeguard times the percentage of plating wastes estimated to be disposed of on-site (35 percent) plus (2) the percentage of treatment and disposal contractors employing the specific safeguard times the estimate of the percentage of waste disposed of off-site (65 percent).

The wastes normally disposed of in this manner are highly toxic chemicals, wastes which are thought to have future recoverable value, and thick, gummy wastes which are difficult to treat or simply difficult to remove from the drums. The specific application of this safeguard to plating wastes is, like plastic/concrete encapsulation, quite limited.

Analysis of the available data shows that no company reported on-site drum burial and only three waste contractors employ drum burial for off-site disposal. Of these three, all report the use of drum burial as one of many disposal safeguards, but do not report what types of wastes are being disposed of in drums. Although all three dispose of plating wastes (along with many other types of wastes), information necessary to determine what percentage (if any) of the plating wastes are being disposed of by drum burial was not available. These three plants represent approximately 6 percent of the treatment and disposal contractors surveyed. Assuming that 65 percent of all plating wastes are disposed of off site, and that these three plants dispose of 6 percent of this by drum burial, it is estimated that a maximum of 4 percent of the plating wastes are disposed of by drum burial.

Leachate Collection and Treatment

Another effective means of preventing ground- or surfacewater contamination is to collect and treat any leachate leaving the land disposal site. Several designs are in operation or under consideration for the collection of leachates from hazardous waste disposal sites. Leachate can be collected by any of the following methods:

(1) Sump at the bottom of each disposal cell.

(2) Infiltration piping, placed in a gravel bed along trenches in the disposal site, leading to a centralized collection sump.

(3) A trench placed around the perimeter of the disposal site to catch any leachate migrating horizontally (vertical migration prevented by impermeable liners of clay or plastic).

(4) Diversion ditches to collect and transport the run-off and leachate to the treatment site.

(5) Groundwater wells with a dual purpose monitoring/leachate collection system.

Once the leachate is collected, it is pumped to either a lined holding pond or to a storage tank and then to a lime or caustic treatment tank. The neutralized effluent can be discharged to the sewer and the precipitated solids returned to the landfill.

The benefit of this type of safeguard is that it provides a final leachate collection system before the wastes can reach the groundwater.

Of course, this safeguard is a backup measure, and is not expected to be employed extensively after the initial operational period of the trench or ramp where the wastes are exposed to the elements. The benefit of this safeguard to plating wastes is that substances such as mobile metal ions from acidified sludges and liquids can be returned to the landfill rather than escaping into the environment.

Analysis of the available data has shown that no on-site and only one off-site disposal operation employs the leachate collection and treatment safeguard. It is estimated, therefore, that less than 1 percent of all plating wastes are disposed of in land disposal sites employing a leachate collection and treatment system.

Chemical Fixation/Solidification

The chemical fixation/solidification of potentially hazardous wastes is a special procedure currently attracting special attention. The process involves the mixing of cementing agents such as portland cement, lime-based mortars, lime-pozzolan cements, certain mixed inorganic-organic material or proprietary silicate compounds with the aim of producing a nontoxic, environmentally safe material which is acceptable for landfill. The mode of operation differs among various companies; one major company, Chem-Fix, Inc., will bring a mobile treatment van to the plant and treat semisolid lagoon wastes on site as a service or will sell the process to the client. Other operators prefer to transfer the wastes to the treatment/disposal site for treatment. After mixing the cementing agent with the wastes, the mixture is pumped on the land for solidification after which it is disposed of to landfill or it may be used as fill dirt for surface contouring.

The benefits of this type of waste treatment in general and for plating wastes specifically are (1) the effective detoxification of polyvalent metal ion hazardous wastes, (2) solidification for ease of disposal, (3) decreased rate of generation of leachate, and (4) reduced disposal cost (because in some states the fixed solidified material is accepted for landfill rather than requiring land disposal).

Analysis of the available data shows that, of those plants reporting, one plant or 2 percent of the plating plants employ on-site chemical fixation/solidification treatment and two plants or 4 percent of the treatment and disposal contractors contacted employ this treatment. While it is not possible to absolutely equate the percentage of plants reporting the use of the process and the percentage of plating wastes being treated or disposed of by that process, they are approximately in a one-to-one relationship. Therefore, it was assumed that 2 percent of the on-site disposed of waste and 4 percent of the off-site disposed of waste are chemically fixed and solidified, or approximately 3 percent of all plating wastes are treated by chemical fixation and solidification.

Waste Inventory, Segregation, and Mapping

The inventorying of incoming wastes and recording of their storage location in a segregated section of the disposal site is another special safeguard. This safeguard requires that (1) different types of wastes, e.g., acids, caustics, polyvalent metal ion sludges or solutions, etc., be identified upon arrival at the disposal site, (2) that these wastes be segregated according to type and stored with similar type wastes, and (3) that the quantity, waste type, toxicity, etc. of each waste and its exact disposal/storage location be recorded.

The benefits of this type of disposal safeguard in general and for plating wastes specifically are (1) potentially toxic elements of a waste material will not be resolubilized or converted to a more potentially toxic form (e.g., heavy metal hydroxides dissolved to soluble ions or Cr^{+3} oxidized to Cr^{+6}) by contact with an oxidant or a waste acid or base indiscriminantly mixed with the wastes, (2) if evidence of leaching is obtained from ground- or surfacewater analyses, the source of the problem can be identified and corrective actions taken (i.e., if the hexavalent chrome or cyanide concentration in the groundwater rises significantly, the storage cell where chrome or cyanide wastes are stored can be excavated and steps taken to eliminate the problem), and (3) if the recovery of a specific type of waste (such as nickel, copper, chrome, zinc, etc.) becomes economically attractive in the future, then disposal cells can be excavated and the valuable waste material collected.

Analysis of the available data for the prevalence of this type of safeguard has shown that no facility, on-site or off-site, presently employs inventorying, segregation, and mapping. However, these procedures are presently employed in radioactive waste disposal operations, and since potentially toxic chemical wastes are often accepted by radioactive waste disposal contractors, it appears likely that at least some small but negligible portion of plating wastes is disposed of in this manner.

Characterization and Environmental Adequacy

The use of special safeguards in the disposal of plating wastes is not widespread. From the estimates presented in Table 44, it can be seen that less than 9 percent (and very possibly much less) of all plating waste disposed of has the benefit of these extra precautionary measures. On the basis of the special safeguard data, plating waste disposal practices have been characterized as failing to employ the best currently available disposal methods for potentially hazardous waste. However, this does not mean that these disposal practices are unsound, or environmentally inadequate. A more extensive review of the environmental adequacy of current disposal practices is presented in a later section.

Private Contractors and Service Organizations

Private contractors and service organizations play a significant role in the treatment and disposal of potentially hazardous wastes generated by the electroplating and metal finishing industry. Treatment and disposal contractors perform for many plants one or all of the following services: (1) hauling (transportation of liquid or solid wastes to a treatment or disposal operation), (2) treatment (either the detoxification of potentially hazardous liquid wastes and/or solid waste treatment, including any of the many methods of dewatering, incineration, or chemical solification), and (3) disposal to land (placement of liquid or solid wastes in or on the land).

In order to completely assess the state of the art of treatment and disposal technologies employed by the electroplating and metal finishing industry and to determine the cost to industry of current and future control practices, it was necessary to analyze the industry for the prevalence of waste handling by private treatment and disposal contractors and service organizations. Analyses included the estimation of the percent of total number of plants having wastes handled by contractors and the identification of the following:

- Contractors, by name and address
- Services provided
- Service costs
- Ultimate disposal method.

To obtain this information, data from the following two additional sources were analyzed:

(1) "An Inventory of Hazardous Waste Management Facilities" (IHWMF), a draft report authored by D. Farb and S. D. Ward, to be issued by the Hazardous Waste Management Division, Office of Solid Waste Management Programs, United States Environmental Protection Agency.

(2) Information supplied by the industry to this study.

The initial step in the acquisition of additional information concerning the services provided by the treatment and disposal contractors was a telephone survey. The organizations contacted in this manner and the information which was obtained are presented in Appendix A. Results of the survey are summarized in Table 45. These data show that approximately 89 percent treat and/or dispose of sludges and 74 percent treat and/or dispose of liquid wastes. On the basis of collection and hauling costs data obtained through the telephone survey, average handling costs were estimated at 0.8¢/liter (93¢/gal), while average treatment and disposal costs were estimated at approximately 2.6¢/liter ($.10 per gal); the total collection-treatment-disposal cost averaged to 5.8¢/liter ($.22 per gal). Nine different treatment and disposal methods were noted in this survey. Of the major treatment and disposal methods, approximately 51 percent of those companies providing data disposed of liquid and solid wastes by

TABLE 45. SUMMARY OF TELEPHONE SURVEY DATA CHARACTERIZING WASTE CONTRACTOR OPERATIONS

	Survey
Services Provided	
Hauling	85 percent
Treatment	83 percent
Disposal	71 percent
Wastes Handled	
Sludge	89 percent
Liquids	74 percent
Solids (dust)	*
Average Service Costs	
Hauling	0.8¢/liter (3¢/gal)
Treatment & Disposal	2.6¢/liter (10¢/gal)
Combined	5.8¢/liter (22¢/gal)
Disposal Methods	
Landfill (unspecified)	51 percent
Pond or Lagoon	10 percent
Land Burial	8 percent
Deep Well Injection	8 percent
Incineration	8 percent
Discharge to Sewer	6 percent
Chemical Solidification	4 percent
Stockpile	4 percent
Outside Disposal	4 percent

* Percentage not available.

landfilling; ponding and lagooning accounted for 10 percent; land burial, 8 percent; deep well injection, 8 percent; and incineration, 8 percent.

The data obtained from the telephone survey, IHWMF report, and the responses to the NAMF questionnaires provided information necessary to compute the distribution of services provided, costs, and the treatment and disposal technologies (Appendix A); however, the data base was insufficient to allow, with any confidence, the extrapolation of these data to the entire industry. In addition, the reliability of the data was questionable, since most of the data were completely unsubstantiated (i.e., information was listed essentially as received by telephone interview and as such not verified). To obtain a better understanding of the treatment and disposal practices used for potentially hazardous wastes, a limited number of plant visits to treatment and disposal contractors were conducted. The objectives of these visits were to:

- Verify and update the information provided in the IHWMF report and facilities' resume obtained over the phone relating to noninventoried plants
- Observe firthand the operations of different treatment and disposal facilities
- Assess and document (if possible) those waste-handling practices which are environmentally adequate.

Of the 67 treatment and disposal contractors identified, 41 were contacted and 23 stated that they would accept visits by contractor personnel. Because of time constraints, it was not possible to visit all 23 plants; however, eleven plant trips were undertaken after the potential visitation sites were screened. The criteria for selection of the visited sites are noted below in order of importance:

- Electroplating or metal finishing wastes treated and/or disposed
- Non-IHWMF plant site
- Plant site not previously visited in IHWMF survey
- Contractor did not require letters of reference, secrecy agreements, or EPA verification, or generally did not display an uncooperative attitude.

Of the six non-IHWMF sites allowing plant visits, two were not considered to be applicable to our study and the remaining four were visited. Table 46 is a listing of the names and states of the eleven treatment and disposal contractors visited.

All plant sites were contacted by telephone prior to the plant visit. At that time the important information on the facilities' resume was updated, or, in the case of non-IHWMF plants a data-acquisition form was completed. Therefore, important data items such as contractor name and address, services provided, service costs, and ultimate disposal methods

TABLE 46. TREATMENT AND DISPOSAL CONTRACTORS HANDLING ELECTROPLATING OR METAL FINISHING WASTES VISITED

(1) Chem-Fix, Inc., Pennsylvania
(2) Approved Chemical Treatment, Inc., Michigan
(3) Erieway Pollution Control, Inc., Ohio
(4) Koski Construction Company, Ohio
(5) Systech, Ohio
(6) BioEcology Systems, Inc., Texas
(7) Conservation Chemical Company, Missouri
(8) Summit National Corporation, Ohio
(9) Valentine Disposal, Pennsylvania
(10) Ohio Sanitation Systems, Inc., Ohio
(11) Warren County Solid Waste Authority, Pennsylvania

were obtained before the visit. Assessments of the environmental adequacy were difficult (if not impossible) from the short inspection tours of the plant facilities (usually not in operation) especially since the site of ultimate disposal was often different from that of the treatment plant.

Treatment and disposal practices can vary widely within a state and often vary markedly from state to state for many reasons (e.g., regulations, availability of land for disposal, etc.). The existence of these wide variations in the treatment or disposal technologies places an economic liability on those areas maintaining tough standards and rigorous enforcement. In many locations untreated waste is discharged directly into the municipal sanitary sewer.

The electroplating wastes received normally come from (1) those large job shops and captive shops in large companies wishing to maintain good public relations and (2) smaller companies which have large, single "dump" quantities of concentrated hazardous wastes. Continued growth or simple maintenance of private contractor operations for the treatment and disposal of electroplating wastes is dependent on the enactment and enforcement of strict hazardous waste disposal regulations.

A composite of the treatment and disposal contractor operations has been prepared through the analysis of data obtained from the IHWMF report, telephone and industry survey data, and information obtained during the plant visits. Figure 7 is a schematic representation of this composite plant.

DESCRIPTION OF WASTE TREATMENT AND DISPOSAL METHODS

Treatment Methods

Potentially hazardous wastes generated by the electroplating and metal finishing industry are found in one of three forms: (1) low-solids slurry, (2) high-solids sludge, and (3) solid waste. Treatment of the low-solids slurry is performed by densification or densification and dewatering to produce a waste more easily disposed of to the land. Concentrated solutions of heavy metals may alternatively be treated by reclamation or chemical fixation and solidification. High-solids sludges and solid wastes are sometimes treated by volume reduction processes (e.g., incineration) to reduce the transportation and final disposal costs.

The methods of treatment discussed below are those used by this industry.

Concentration and Dewatering

Liquid wastes such as spent plating solutions, rinse waters, acid baths, and alkaline cleaners not collected and disposed of by a private contractor, reclaimed or sewered, are treated in an on-site water pollution

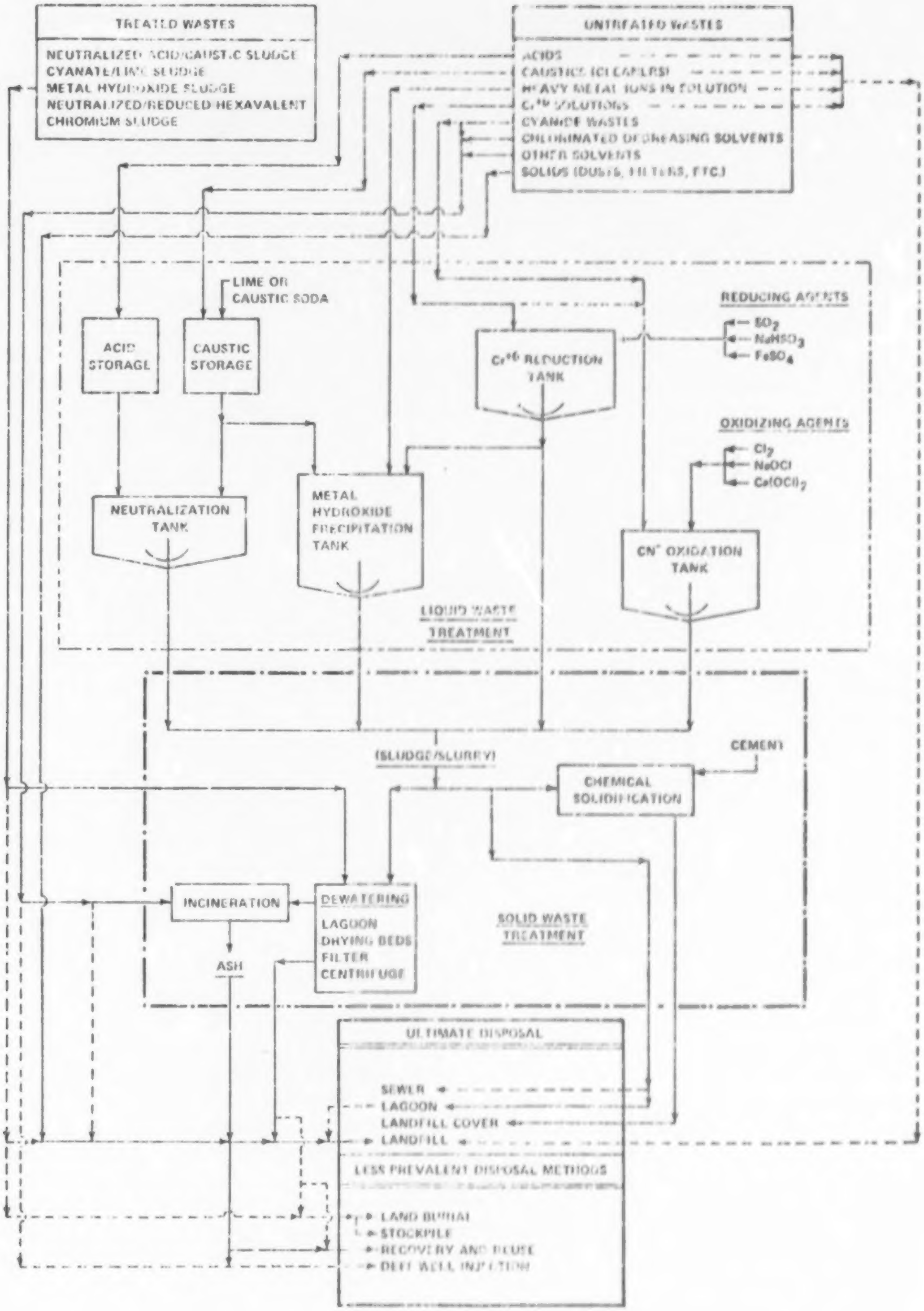

FIGURE 7. COMPOSITE SCHEMATIC OF ELECTROPLATING AND METAL FINISHING HAZARDOUS WASTE TREATMENT AND DISPOSAL CONTRACTOR OPERATIONS

NOT REPRODUCIBLE

control facility. Those operations that are used to treat the waste by concentrating the solids produced in the water pollution control facilities are as follows: settling and final burial in a permanent lagoon; settling and periodically removing sludges from a holding lagoon; direct dewatering either by filtration or centrifugation; settling in a holding tank with clarification; or settling in a holding tank with clarification followed by dewatering.

A brief description of the concentrating and dewatering treatment technologies used follows:

Lagooning. A lagoon is a depression in the land for holding brackish waters. Many lagoons are of natural formation; however, the majority used in waste disposal operations are manmade on specific selected sites. The lagoon may be unlined or it may be lined with clay or plastic sheets which are overlayed with about 1 foot of gravel.

The accumulated sludges may be removed and taken to a permanent landfill or left in the lagoon. In a permanent lagoon the solids ultimately are covered when full with about 6 feet of dirt.

Since capital and land are invested in the lagoon, many plants remove the settled sludge after several years of operation and dispose of it, freeing the lagoon for additional service. The simplest method of disposal is to transfer the sludge to a landfill. A safer method is to chemically or physically fix the sludge by mixing with cement, asphalts, plastics, or proprietary agents to form a hard-setting, leach-resistant medium, with the sludge making it more durable for long-term storage. The converted mix may be deposited in a wide variety of landfills.

Direct Dewatering, Including Holding Tanks. Instead of settling in a lagoon over a period of months or years, many plants dewater their slurries to sludges immediately. This treatment is used for a variety of reasons, some of which are as follows: (1) some states do not allow lagooning; (2) sometimes lagoons overflow, leak, or break; or (3) land is not available or too expensive for lagooning, especially in larger cities. In many of these instances, direct dewatering is the only treatment available. The degree of dewatering depends on the local situation, especially in relation to the distance between the plant and the disposal site.

The least complex of these treatment methods is similar to lagooning and is simply a holding tank wherein solids may be concentrated to about 1 to 2 percent. When dense solutions are necessary, filters and/or centrifuges must also be used, which require a greater penalty in that more capital must be invested and therefore higher overall costs result. To improve on the densification of slurries, a thickener or clarifier may be added to the tank. This operation increases the solids content to about 2-3 percent. A thickener, of which there are several different types, consists of a shallow, cylindrical settling tank, equipped with a central feed well, peripheral overflow collection trough, pump-regulated sludge discharge outlet at the bottom, and a slowly revolving, centrally located shaft equipped with radial arms and plow blades for moving the settled sludge gently to the central sludge outlet.

These thickened slurries may be sent directly to a lagoon or to a landfill, or may be further treated by filtration or centrifugation. Slurries may also bypass tank settling and/or thickening and be processed by dewatering directly by any suitable dewatering process.

Filtration. Filtration is the separation of the solid and liquid phases by means of a porous membrane. This separation may be effected on a vacuum-drum filter or a plate-and-frame filter.

A continuous vacuum-drum type filter is a cylinder whose periphery forms the filtering surface. The external surface is generally used for depositing the solids and is divided into separate compartments. Each compartment is separately connected to an automatic control valve which regulates the period of vacuum for forming and drying the filter cake, and the application of compressed air for discharging the filter cake. The slurry feed deposits a sludge on the external surface of the filter when a vacuum is applied. As the porous drum rotates and leaves the feed bath, carrying with it the sludge, the sludge is dried and finally discharged into a receiving hopper before the cycle is repeated.

In a plate-and-frame type unit, a filtering medium is stretched over a frame provided with channels for the collection and drainage of solutions, thus allowing the solids to be recovered. The slurry to be filtered is forced under pressure into the space between the filter medium and the frame. A number of these units in series constitute a plate-and-frame filter. Provisions are made for slurry feed to each frame and for discharge of filtrants from each plate. When filtration is completed and feed stopped, the plates and frames are separated, thus allowing the sludge to discharge to a hopper. A sludge of 20 to 25 percent solids may be expected from this mode of separation.

Centrifugation. A centrifuge is a machine designed to apply a centrifugal force to the waste material. This machine may be used to separate the liquid and solid phases by allowing the liquid to pass through a supported filtering medium (cloth screen) to a discharge port while catching and holding the solids. When used to separate sludges from slurries in a wastewater treatment facility, the solids content is increased to about 20 to 25 percent in a basket-type unit wherein the spinning basket, similar to a household washing machine, discharges water through a peripheral screen.

Reclamation. Sludges and liquids from electroplating and metal finishing wastes contain valuable metals and other materials which may, at least in theory, be recovered by chemical treatment.

In determining the practicality of reclamation schemes, the economic trade-offs and other factors must be considered, e.g., recovery costs versus virgin materials costs, energy requirements and availability of energy, and the cost of environmental protection.

Many of the techniques for materials reclamation are well developed and available for use when economic factors are favorable or regulations encouraging reclamation are adopted. For example, the reclamation of solvents currently is practiced in many cases and techniques for concentrating aqueous liquids (e.g., reverse osmosis and evaporation) have been demonstrated.

Viable techniques for the reclamation of metal values from sludges have not been developed. Some research has been conducted on various recovery techniques, but no sludge recovery methods have been demonstrated on a commercial scale in this country.

Chemical Fixation/Solidification

Both sludges and slurries can be mixed with solid-setting materials to form a body which keeps leaching to a minimum. Some of those solid-forming bodies are cement, asphalts, plastics, or proprietary materials. As practiced, sludges are scooped from a lagoon, mixed with the solid-setting material and returned to set. The set product, which forms a friable mix, is broken up and disposed of in a landfill. In another practice, spent pickle liquor, as a slurry, is mixed with a proprietary material which forms a thickened mass; upon solidification, the mass is broken up and disposed of in a landfill.

Incineration. Incineration is the application of heat in the presence of oxygen and a combustible fuel to cause burning. As applied to the electroplating and metal finishing industry, it is the formation of reduced volume of process wastes and degreaser sludges via the oxidation of solvents, sludges, inerts, and metal-containing solid wastes. Incineration is not widely practiced in this industry since combustible fuels are not available or are too costly. Only two respondents reported the use of incineration in the survey--one for solid wastes and the other for organic liquids. Current and potential regulatory demands for controlling air pollution from incineration require more sophisticated and more costly systems which make reclamation and land disposal the preferred methods.

Disposal Methods

Solid and semisolid wastes from the electroplating and metal finishing industry often are destined for some form of land disposal. Below are brief descriptions of these disposal methods found to be employed by either the job shops themselves, or by contractors employed to collect and dispose of the wastes.

Sewer Dumping or Sluicing

Some political divisions allow the dumping of untreated wastes into the sewer system upon notification of the sewage plant operating personnel. Many of the electroplaters avail themselves of this service, even though a charge is usually assessed. However, this method of treatment is discouraged since plating solutions, when not sufficiently diluted or neutralized, can cause serious structural damage due to corrosion, and, in some cases, may even cause blockage of sewer lines. Plating wastes, especially those containing cyanides, can create toxic conditions in the sewer circuit, making working conditions intolerable. In addition, these wastes may have a deleterious effect on the operation of the sewage plant, in that primary sludge precipitation may overtax the filtration capacity, bacterial colonies may lose or diminish their effectiveness either in primary or secondary digestion systems, and excess heavy metal ions may be discharged by the treatment system and enter navigable streams.

Open Dump

An open dump may be a disposal site owned and operated by private concerns or individuals where anybody can dump waste materials for a fee. Operators of open dumps accept residential, commercial, industrial, and sometimes potentially hazardous wastes when approved by state, EPA, and local health authorities. Open dumps also may be owned and operated by an industrial concern for its own use. Wastes are compacted when dumped and left uncovered until the site is completely filled. Monitoring wells are not normally employed.

Municipal Landfill

Municipal landfills are disposal sites owned and operated by local political subdivisions. The large majority of the wastes destined for these landfills are of commercial and residential origin, with the quantity of potentially hazardous waste usually at a minimum. With the exception of compacting with a bulldozer and covering the disposed debris daily with about 6 inches of dirt, as in a sanitary landfill, additional precautions are seldom taken to insure protection of the environment.

Special Landfills

Approved landfills are disposal sites where precautions are taken in the selection, control, and monitoring of the sites to insure that leaching will be minimized. In order to insure long-term protection of the environment from potentially hazardous waste migrations, either horizontally or vertically, the geological conditions are appraised for favorable entrapment and storage.

When the approved landfill is considered to be a secured landfill, the following additional safeguards are taken. Where geological conditions are inadequate to prevent these migrations, impervious liners of clay, asphalt, or concrete are demanded. Additionally, an inventory and mapping of the hazardous waste burial site is required so that retrieval (if necessary) is possible. Some special and/or secured landfills require encapsulation in drums or containers which give some degree of control of leaching.

The selected site should undergo extensive geological evaluation for hydraulic connections to ground and surface waters. Subsoil characterizations should also be made to determine the need for impervious liners to prevent horizontal and vertical migration of the hazardous constituents. A characterization of the surrounding groundwater and surface waters before the site is activated is also required. Facilities for leachate collection are essential for liquid, low-solids slurries and/or soluble metal wastes. In addition, the site should be operated in such a fashion so as to permit the disposal of similar materials in separate and isolated cells. The location of each cell should be identified and mapped and its contents recorded. From these records, problem areas could be easily located, and the wastes contained in these areas could then be removed. It would also permit the excavation for recovery of such wastes for resource reclamation. Since long-term physical protection of the environment is the goal, surveillance and monitoring of the disposal sites, including regular analysis of ground and surface waters for changes in background levels, are necessary. There are several designs in operation or under consideration to facilitate leachate collection (for surveillance and for treatment, if necessary) from potentially hazardous waste disposal. Once the leachate is collected, it is neutralized with a lime treatment to precipitate metal hydroxides. The dewatered solids can be returned to the disposal site and the effluent can be discharged to the sewer.

DEVELOPMENT OF TECHNOLOGY LEVELS

The results of the analysis performed on the identified treatment and disposal technologies practiced by the electroplating and metal finishing industry were used to develop three levels of technology for the industry. The technology includes processes employed for the treatment of a waste stream from its point of identification to the waste's ultimate disposition. The three levels of technology are as follows:

Level I - Technology employed by typical facilities, i.e., a broad average practice of treatment and disposal.

Level II - Best technology currently employed and representing the soundest process from an environmental and health standpoint currently practiced in at least one location on a commercial scale.

Level III - Technology either in operation or being developed necessary to provide adequate health and environmental protection.

In the development of the technology levels, selected factors were used to assess the adequacy of the technology related to health and environmental protection. Each level is discussed in detail in the following sections. A summary of each level and its assessment is given in Tables 49A through 49D.

Prevalent Treatment and Disposal Technology
Level I

The broad average treatment and disposal technology for those potentially hazardous wastes destined for land disposal, defined as Level I, is discussed below for the following four major waste streams: (1) water pollution control sludges/solutions, (2) process wastes, (3) degreaser sludges, and (4) electroless nickel sludges.

Water Pollution Control Sludge

The technologies employed to separate the sludge from the treated wastewater used by the 50 job shops in the survey sample are given in Table 47. The most prevalent treatment technology is solids concentration through the use of simple settling devices (e.g., lagoons, holding tanks or clarifiers) to create a 1 to 5 percent solids sludge for disposal. The disposal methods employed by job shops for the various waste streams are summarized in Table 48. The prevalent disposal technology for the water pollution control sludge (after the solids concentration treatment) is simple land disposal (including surface and deep burial, open dumps, and municipal landfills). Sixteen of the 27 plants (59 percent) which identified their disposal method for water pollution control sludge employ this disposal method. Thirty-three of the 50 plants (66 percent) in our survey employ off-site disposal.

Process Wastes

The prevalent treatment and disposal technology for process wastes (comprised of dusts, contaminated metal scrap, plating racks, high-solids sludges, and miscellaneous process solid wastes) is disposal in municipal landfills. Seven of the 11 plants (64 percent) which identified their waste disposal method employ municipal landfills. Nineteen of the 27 plants reporting (70 percent) dispose of their process wastes off site.

Degreaser Sludges

The prevalent treatment and disposal practice for solvent wastes is reclamation. Fifteen of the 16 plants (94 percent) included in this survey employ reclamation, sale, or on-site recovery and reuse. Ten of the 16 plants (63 percent) employ off-site reclamation/disposal. When reclaiming the solvent on site, a potentially hazardous degreaser sludge is

TABLE 47. TREATMENT METHODS USED BY THE SAMPLED JOB SHOPS TO SEPARATE SOLIDS FROM TREATED WASTEWATER

	No. of Plants	Percent
Treatment Method		
Lagoon	8	16
Holding Tanks	13	26
Tank and Clarifier	4	8
Clarifier and Dewatering	2	4
Direct Dewatering	10	20
Unknown	13	26
Total Plants	50(a)	
Dewatering Methods		
Filtration	10	83
Centrifuge	2	17
Total Plants	12	

(a) The number of shops reporting disposal was 50; more than one treatment is used in some shops.

TABLE 48. DISPOSAL METHODS USED BY THE SAMPLED JOB SHOPS FOR SLUDGES AND PROCESS WASTES

Disposal Method	Number of Plants Using Disposal Method for Waste	
	Water Pollution Control and Other Sludges	Process Wastes
Permanent Lagoon (on site)	3	-
Surface Burial (on site)	3[(a)]	1
Deep Burial (on site)	1	-
Open Dump (on site)	1	-
Open Dump (off site)	5	2
Municipal Landfill (off site)	6	7
Special Landfill (off site)	2	1
Recovery and/or Reuse (on site)	-	-
Reclamation (off site)	4	-
Sell (off site)	2	-
Fate Unknown	23	16
Off-Site Disposal	33	19
On-Site Disposal	17	8
Total Plants	50	27

(a) Includes two plants which employ chemical fixation/solidifation.

created. This waste may be combined with those solvents not reclaimed and sent to the water pollution control facilities; it is ultimately disposed of to the land along with the WPC sludge or may be included with the process waste stream. Regardless, the prevalent disposal practice for solvent sludge is nonapproved land disposal.

Electroless Nickel Wastes

The prevalent practice for disposal of electroless nickel wastes is disposal to landfills. They normally are incorporated with the water pollution control sludges for disposal.

Evaluation of Prevalent Treatment/Disposal Technology (Level I)

The present broad average treatment/disposal technologies employed by the electroplating and metal finishing job shops and by the printed circuit job shops were evaluated by a set of 12 factors. These evaluations are summarized in Tables 49A (water pollution control sludges), 49B (concentrated inorganic solutions), 49C (process wastes), and 49D (solvent/solvent sludges). More detailed consideration of those factors affecting the adequacy of Level I Technology for each waste stream is given in the following sections.

Water Pollution Control Sludge

The prevalent treatment/disposal technology for water pollution control sludge is solids concentration to 1 to 5 percent, followed by simple land disposal. The waste is an aqueous slurry of metal hydroxides. The Level I technology is considered inadequate to provide health and environmental protection, primarily because of the potential contamination of groundwater or surfacewater supplies possible with this method of disposal. Metal hydroxides, when exposed to an acid environment (possible through contact with organic acids resulting from municipal refuse decomposition), become resolubilized. The metal ions can then enter the groundwater supplies, when water table levels are high or by being carried with rain water percolating through the land disposal site.

Process Wastes

The prevalent treatment/disposal technology for process solid wastes is municipal landfill disposal. Process wastes are comprised of solids and semisolids contaminated with toxic metals from the metal finishing operations. These wastes are not normally regarded as hazardous by the industry and are therefore disposed of with nonhazardous plant trash

TABLE 49A. SUMMARY OF TREATMENT AND DISPOSAL TECHNOLOGIES (WATER POLLUTION CONTROL SLUDGE AND ELECTROLESS NICKEL SLUDGE)

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Physical and Chemical Properties	1 to 5 percent solids sludge containing heavy metal hydroxides in aqueous solution	Same as Level I except sludges would be dewatered to ≥20 percent solids	Same as Level II
Description of Residual Wastes	None	None	None
Factors Affecting Hazardousness	pH of sludge and disposal site: Under conditions of low pH due to acid conditions resulting from organic material decay, metal ions in precipitated metal hydroxides can become remobilized with metal ions going into solution	Slight dissolution and remobilization of metal hydroxides by rain water seepage is possible	Same as Level II
Treatment/Disposal Technology	Sludge is concentrated to 1-5 percent solids through the use of simple settling devices (lagoon, holding tanks or clarifiers). The disposal method employed is simple land disposal (including surface and deep burial, open dumps, and municipal landfills)	Sludge is concentrated to ≥20 percent solids through the use of dewatering devices (centrifugation or filtration). Disposal method employed is an approved sanitary landfill.	Sludge is dewatered to ≥20 percent solids. The disposal method employed is a secured sanitary landfill.
Estimate of number of plants now using technology	16 plants in the sample of 27 identifying their WPC sludge disposal method (59 percent) employ the prevalent treatment/disposal technology	2 plants in the sample of 27 identifying their WPC sludge disposal method (7 percent) employ the best treatment/disposal technology	None
Adequacy of Technology	Simple land disposal does not provide satisfactory ultimate disposal. Leachate formation and migration are not sufficiently limited	Approved sanitary landfills provide adequate short term disposal; long term protection, however, is not assured	Secured sanitary landfills provide adequate long-term protection
Problems and Comments	Fate of wastes hauled by contractor to land disposal sites often unknown by generator unless liability lies with generator. This waste is generated only by those facilities who presently treat their wastewater. Introduction of toxic substances into groundwater supplies	Same as Level I	Secured landfills, because of wastes segregation and mapping, wastes can be excavated for future recovery
Non-Land Environmental Impact	Leaching of metals in solution from simple land disposal can result in introduction of toxic substances into water supplies	Potential contamination of water supplies.	None

NOT REPRODUCIBLE

TABLE 49A. (Continued)

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Compatibility of Existing Facilities	The difficulty of retrofit to existing facilities to the treatment/disposal technology is moderate. Solids concentration requires space not normally available to urban plating operations. The difficulty of retrofit to the simple land disposal would be minimal.	The difficulty of retrofit to existing facilities would be high. The space requirements for solids concentration and for dewatering would not normally be available to urban plating operations. In addition, the availability of approved landfills is severely restricted. Disposal by this method would be very difficult in most sections of the country.	The difficulty of retrofit to existing facilities would be very high. Problems include space limitations for solids concentration and dewatering equipment. The most significant limitation is the absence of any secured sanitary landfills.
Monitoring and Surveillance Techniques	No monitoring or surveillance techniques are practiced for simple land disposal	Approved landfills include sample wells for groundwater monitoring and surveillance. Analyses include heavy metal ions, cyanide, and pH.	Secured landfills include drainage canals and moats leading to a well where leachate rates are monitored by regular sampling and analysis. Analyses performed are similar to Level II.
Installation Time	If an existing simple land disposal site is available to the plater (as would normally be the case) the time to implement this disposal practice would be minimal. If a new facility were required, the installation time required would be extended. Simple land disposal sites normally employ natural land depressions, gullies, or pits. The time necessary to prepare the site (since site preparation is minimal) is relatively short, approximately 6 months to 2 years.	Approved landfills require extraordinary precautions in site selection, control and monitoring. Installation time is therefore usually long. Because of political and economic considerations, including availability of equipment, installation time can be as long as 2-5 years.	Secured landfills include the site selection, control and monitoring required in Level II, plus additional disposal safeguards. Installation time can be as long as 3-5 years.
Energy Requirements	Energy requirements for simple treatment and disposal include (1) slurry pumping to settlers and to disposal vehicles (low), and (2) energy for truck transporting the waste to the land disposal site (low).	Energy requirement includes (1) pumping of slurries to settling devices (low), (2) dewatering by filtration or centrifugation (high), (3) truck transportation to approved landfill (low), and (4) bulldozer-applied daily cover at disposal site (low).	Same as Level II. Additional energy could be consumed if on-site leachate treatment was required.

NOT REPRODUCIBLE

TABLE 49B. SUMMARY OF TREATMENT AND DISPOSAL TECHNOLOGIES

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Physical and Chemical Properties	The wastes are liquid solutions comprised of aqueous solutions of heavy metals, including precious metals, chromium, nickel, and copper (etching solutions)	Same as Level I	Same as Level I
Description of Residual Wastes	None	None	None
Factors Affecting Hazardousness	Toxic heavy metal ions in solution can enter groundwater supplies from on-site leaks and spills	Same as Level I	Same as Level I
Treatment/Disposal Technology	Reclamation of valuable metal ions is the prevalent treatment and disposal technology	Same as Level I	Same as Level I
Estimate of Number of Plants now Using Technology	15 plants in a sample of 17 plants identifying treatment/disposal method (88 percent) employ Level I technology	Same as Level I	Same as Level I
Adequacy of Treatment	Reclamation is adequate to provide health and environmental protection	Same as Level I	Same as Level I
Problems and Comments	Only those selected, rich solutions containing high value metal ions can now be economically reclaimed	Same as Level I	Same as Level I
Non-Land Environmental Impact	None	None	None
Compatibility of Existing Facilities	The difficulty of retrofitting existing facilities to reclamation is minimal if an off-site contractor handles the wastes. If an on-site installation is required, the difficulty of retrofit is moderate. Principal limitations are (1) costs, (2) time to order, receive, and install equipment, and (3) space limitations.	Same as Level I	Same as Level I

NOT REPRODUCIBLE

TABLE 49B. (Continued)

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Monitoring and Surveillance Techniques	Monitoring and Surveillance of concentrated inorganic solution recovery is not practiced	Same as Level I	Same as Level I
Installation Time	Minimal time would be required to implement a reclamation operation if operations are conducted by off-site contractors. Approximately 6 months to 1 year would be required to specify, receive and install an on-site reclamation unit.	Same as Level I	Same as Level I
Energy Requirements	Energy requirements for an electrochemical plating/recovery unit are moderate (on-site).	Same as Level I	Same as Level I

NOT REPRODUCIBLE

TABLE 49C. SUMMARY OF TREATMENT AND DISPOSAL TECHNOLOGIES (PROCESS WASTES)

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Physical and Chemical Properties	Solid and high-solids sludges contaminated with toxic heavy metal salts	Same as Level I	Same as Level I
Description of Residual Wastes	None	None	None
Factors Affecting Hazardousness	Toxic heavy metals in contaminated wastes can become mobilized and enter groundwater supplies from disposal site leachate	There is a possibility of mobilization of metal ions by rain water seepage in approved landfills	Disposal in a secured sanitary landfill
Treatment/Disposal Technology	Disposal in municipal landfills is the prevalent treatment and disposal technology	Disposal in an approved sanitary landfill.	Disposal in a secured sanitary landfill.
Estimate of Number of Plants Now Using Technology	7 plants in the sample of 11 identifying their waste disposal methods (64 percent) employ municipal landfill disposal	One plant in the sample of 11 identifying their disposal technology (9 percent) employ disposal in an approved landfill	None
Adequacy of Treatment	Municipal landfills do not provide satisfactory ultimate disposal. Leachate formation and migration are not sufficiently limited.	Adequate short term disposal is provided by an approved landfill; long term protection, however, is not assured.	Adequate long term protection is provided by a secured landfill.
Problems and Comments	The fate of wastes hauled by contractor to land disposal sites is often unknown by generator unless liability lies with generator. Process wastes are not uniformly regarded as a potentially hazardous waste; therefore they are normally disposed of with the non-hazardous plant trash	There are no major problems with approved landfills except where noted elsewhere	Secured landfills, because of waste mapping and segregation, can be excavated for future treatment or recovery
Non-Land Environmental Impact	Leaching of solbilized metals from municipal landfills can result in the introduction of toxic substances into groundwater supplies	Same as Level I	None
Compatibility of Existing Facilities	The difficulty of retrofitting existing facilities is minimal	The difficulty of retrofit of existing facilities to an approved landfill varies with location. In most locations, approved landfills do not exist and therefore difficulty of retrofit is very high. In locations where such facilities are in operation, retrofit is only limited by the economic costs to transport the wastes to the disposal site.	The difficulty of retrofit of existing facilities to secured landfills is extremely high.

NOT REPRODUCIBLE

TABLE 49D. SUMMARY OF TREATMENT AND DISPOSAL TECHNOLOGIES (DEGREASER SLUDGES)

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Physical and Chemical Properties	The waste stream is an organic liquid containing heavy metal contaminants. The solution is composed of chlorinated and normal hydrocarbons. Solvent sludges are a low-solids sludge contaminated with toxic heavy metals	Same as Level I	Same as Level I
Description of Residual Wastes	None	None	None
Factors Affecting Hazardousness	Toxic heavy metal ions and residual solvents in the sludge can enter water supplies from on-site leaks and spills and through improper clean-up operations	Same as Level I	Same as Level I
Treatment/Disposal Technology	Degreaser sludges are discharged to the water pollution control system or included with the process waste stream	Sludges are disposed of in an approved sanitary landfill	Same as Level I for spent solvent sludges. Solvent sludges are disposed of in a secured sanitary landfill
Estimate of Number of Plants Now Using Technology	No survey data are available on final disposal of degreaser sludges	Same as Level I	Same as Level I
Adequacy of Treatment	Simple land disposal of sludges is an inadequate disposal method to provide health and environmental protection.	Same as Level I for spent solvents. Disposal of sludges in an approved landfill provides adequate short-term disposal.	Treatment/disposal practices employed are adequate
Problems and Comments	When solvents are reclaimed on site, a degreaser sludge is produced which requires disposal. This waste is combined with those solvents not reclaimed and sent to the WPC facility (and ultimately disposed of to land) or included with the process waste stream destined for land disposal. Potential contamination of water supplies	Same as Level I.	None

NOT REPRODUCIBLE

TABLE 49D. (Continued)

Factor	Level I, Prevalent Technology	Level II, Best Available Technology	Level III, Adequate Health and Environmental Protection
Non-land Environmental Impact	Sludges destined for non-approved disposal can contaminate the ground water through disposal site leaching.	Leachate can escape into the environment over a long time period.	Leachate can escape into the environment over a long time period.
Capatibility of Existing Facilities	**The difficulty of retrofitting existing facilities is minimal**	Same as Level I for spent solvent solutions. **Solvent sludge disposal in retrofitting is high because of the absence of approved landfill sites in many sections of the country**	Same as Level I for degreaser sludges. Degreaser sludge disposal in retrofitting is extremely high because no secured landfills (excluding radioactive waste disposal facilities) exist and the cost and time to construct such a facility is extremely high
Monitoring and Surveillance Techniques	No monitoring or surveillance techniques are employed	Not practiced	Monitoring and surveillance techniques should be employed for degreaser sludges disposed of in a secured landfill
Installation Time	No time is required for solvent recovery to be implemented if operations are conducted by an off-site contractor. Approximately 6 months to 1 year are required to specify, receive, and install an on-site reclamation unit. There would be no time limitation to apply the prevalent degreaser sludge disposal technology for simple land disposal.	Same as Level I for spent solvent solutions. The time to install an approved sanitary landfill for **degreaser sludge disposal is approximately 2-5 years (required for site selection, approvals, and construction).**	Same as Level I for spent solvent solutions. Approximately 3-5 years would be **required to plan and construct a secured sanitary landfill for solvent sludge disposal**
Energy Requirements	Energy requirements for a distillation type reclamation operation are high. **Energy requirements for the disposal of the degreaser sludge, for slurry pumps (low), truck transportation (low), and disposal is low.**	**Same as Level I**	**Same as Level I**

NOT REPRODUCIBLE

in municipal landfills. This disposal method is not considered adequate for health and environmental protection because of the potential for ground water or surface water contamination. Toxic metals included in the process wastes can become solubilized through contact with organic acids present in the disposal site. The metal ions can be carried with rain water percolating through the disposal site and into the groundwater supply.

Degreaser Sludges

The prevalent treatment/disposal technology for spent solvents is reclamation. The solvents used in metal cleaning operations become contaminated with toxic metals. These metals are removed in the reclamation operation and transferred to a solvent sludge. The treatment/disposal technology for solvent wastes is considered adequate for health and environmental protection. However, the prevalent disposal practice for solvent sludges, simple land disposal with the process wastes or water pollution control sludges, is considered inadequate because of potential groundwater or surfacewater contamination. Metal oxides or hydroxides in the waste can become solubilized in an acid environment and be carried with percolating rain water to groundwater supplies. Any residual solvent also is potentially hazardous.

Evaluation of Best Technology Currently Employed (Level II)

From the technologies identified in the survey sample, the soundest process from an environmental and health standpoint currently in use in at least one location on a commercial scale was selected as the best technology currently employed (Level II technology). Evaluations of the treatment/disposal technologies are summarized in Tables 49A through D for water pollution control sludge, concentrated inorganic solutions, process wastes, and solvent/solvent sludges, respectively. More detailed consideration of the Level II technologies' adequacy is described below for each waste stream.

Water Pollution Control Sludges

The best treatment/disposal technology for the water pollution control sludge involves (1) solids concentration, (2) dewatering to greater than or equal to 20 percent solids, and (3) disposal in an approved sanitary landfill. The additional safeguards above the Level I technology include the dewatering operation which produces a high-solids (increase from 1 to 5 to 20 percent solids), lower volume, sludge cake. The most important additional safeguard is the change from simple land disposal (surface burial, open dumps, municipal landfills, etc.) in Level I technology to an approved sanitary landfill for Level II technology. An approved sanitary landfill involves a disposal site where precautions have been taken in the areas of site selection and leachate control and monitoring. Disposal of water pollution control sludges in such a disposal site is considered adequate for short-term disposal. Long-term protection, however, cannot be assured since surface run-off and rain water can still percolate through the disposal area, leading to leachate formation. If the impervious barriers placed in the bottom of the landfill should become ruptured, break, or otherwise fail, no means are available to collect the leachate for treatment or excavate the problem hazardous waste.

Process Wastes

The best treatment/disposal technology for the contaminated solid and semisolid process wastes is disposal in an approved sanitary landfill. As noted in the best technology section for WPC sludges, an approved sanitary landfill is considered adequate for short-term disposal. However, because such facilities do not include the means for leachate collection and treatment, waste segregation and mapping, long-term protection of the environment cannot be assured.

Degreaser Sludges

The prevalent treatment/disposal technology for solvent wastes is reclamation; it is also considered the best practice. Reclamation of solvent wastes is considered adequate to provide health and environmental protection.

The best treatment/disposal technology for solvent sludges is disposal in an approved sanitary landfill. This disposal method is considered adequate for short-term disposal. Long-term protection, however, cannot be assured because of the lack of facilities for leachate collection and treatment, waste segregation and mapping.

Evaluation of Treatment/Disposal Technology Considered Adequate for Health and Environmental Protection (Level III)

The technology identified here may be identical to the two previously cited technology levels or it may be more or less sophisticated. The identified technology may include pilot or bench-scale processes. In any case, the technology must provide adequate health and environmental protection.

The technology identified as adequate in this study consists principally of the present best technology described in the previous section with some modifications in the preparation and operation of approved sanitary landfills.

The level of technology considered adequate for each waste stream has been evaluated for 12 factors in Tables 49A through D. The adequate disposal practices are discussed briefly for each waste stream below.

Water Pollution Control Sludge

The treatment/disposal technology considered environmentally adequate for the water pollution control sludge includes solids dewatering and disposal in a secured sanitary landfill. A secured sanitary landfill employs the basic site selection, and leachate control procedures described for an approved sanitary landfill with the additional safeguards discussed in a previous section of the report.

Process Wastes

The treatment/disposal technology considered adequate for health and environmental protection for process wastes is disposal in a secured sanitary landfill. As noted previously for water pollution control sludges, a secured landfill includes modifications to an approved landfill to provide additional safeguards to assure long-term environmental protection.

Degreaser Sludges

Reclamation of spent solvents is considered both the best and the most environmentally adequate treatment/disposal technology.

The disposal practice considered environmentally adequate for solvent sludge wastes is disposal in a secured sanitary landfill. As noted earlier, the modification of the best disposal practice, approved landfill disposal, to the secured classification allows assurance of long-term protection of health and the environment.

IV. COST ANALYSIS

INTRODUCTION AND METHODOLOGY

This section presents a cost analysis of the treatment and disposal techniques of those potentially hazardous wastes generated in the electroplating and metal finishing industry which are destined for land disposal. The electroplating and metal finishing wastes are grouped into four distinct waste streams:

(1) Water Pollution Control (WPC) Sludges
(2) Process Wastes
(3) Degreaser Sludges
(4) Electroless-Ni Bath Treatment Sludge.

The engineering approach method of cost analysis was used to generate waste treatment and disposal costs. The engineering approach involves the estimation of capital and average operating costs on a one-time basis without any regard to the life of the project. The entire capital cost is amortized to obtain annualized capital costs. No consideration is given to cash flows, incremental costs, or expected project benefits.

The simulation technique of cost estimation using three different sized model plants was employed. The detailed descriptions of the various electroplating and metal finishing operations, together with the calculations related to the different quantity of waste generated in the 16-man, 38-man, and 87-man model plants are presented in Appendixes B, C, and D, respectively.

For estimating the model plant operating costs, capital costs for various items of equipment for the WPC sludge dewatering, storage of the several wastes, etc., were derived from literature or trade sources. Equipment cost data were adjusted to show December, 1973, costs using the Marshall and Stevens Equipment Cost Index published periodically in Chemical Engineering (McGraw-Hill, Inc.). All capital and operating costs for the model plants were based on December, 1973, dollars. For estimating model plant operating costs, a 10-year straight line depreciation (i.e., 10 percent per year) was applied to the capital investment cost for the waste dewatering and waste storage equipment. An annual interest charge of 10 percent was also applied to the capital investment on this equipment. Labor costs for sludge dewatering and handling of the several stream wastes were based on a charge of $8/man hour. Annual maintenance costs were estimated to be 5 percent of the capital investment costs, while annual costs for taxes and overhead were determined to be equal to 0.8 percent of capital equipment costs. The principal items influencing the capital and operating costs for waste disposal contractors and/or landfill operators include those for land, site development, equipment, depreciation, interest, equipment rental, labor, power, maintenance and repair, materials, administration, and overhead.

The following sections of the report provide considerable data, gathered from many sources, on contractor charges for hauling wastes, contractor charges for combined hauling-treatment (if any)-disposal of wastes, landfill operating costs, and landfill fees. The manner in which these data were used to arrive at representative waste treatment and disposal costs for the different treatment-technology levels is discussed below.

Contractor Treatment and Disposal Costs

Versar, Inc. Survey for EPA

A survey of approximately 50 hazardous waste treatment and disposal contractor companies, which collectively represent all sections of the continental United States, was made in early 1974 by Versar, Inc. for the Office of Solid Wastes Management Programs, EPA, Washington, D.C.* Information gathered included the type of operation (hauling, treatment, and/or disposal), type of waste (sludges, liquids), service cost, and ultimate disposal facility used. Of the 50 contractors, 18 (36 percent) supplied service cost estimates for hauling, treatment, and/or disposal activities. Most of the cost figures were expressed as cents/gal; however, a few others used mixed units such as \$/cu ft, \$/lb of specific substance, \$/mile per truck, etc.

Most electroplating and metal finishing facilities pay a fee to the private contractors for handling sludges, dusts, and other wastes. The fees paid are not the actual cost of handling waste, but they represent the charges imposed on the customer by the contractor. The charges include the contractor's expenses plus overhead and profit.

Table 50 contains the data on contractor fees for waste handling which were derived from the Versar, Inc. survey.* Although the available data and descriptive information are limited, some generalizations can be made about the various categories.

Hauling.** As would be expected, "Hauling" is the only category which includes a mileage rate. Data are too limited to permit mileage generalizations. In addition to the mileage fee, a "Hauling" fee may be charged on a per-gallon basis, ranging from 0.26 to 0.79¢ per liter (1 to 3¢ per gallon). No specific provisions are apparent in Table 50 for toxic wastes of one sort or another, however, it can be expected that many firms will charge special handling fees for toxic wastes and their unit charges could well exceed 0.79¢ per liter (3¢ per gallon).

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* "An Inventory of Hazardous Waste Management Facilities", Versar, Inc. for U. S. EPA, August, 1974.

** See foot note on following page.

Footnote ** (from previous page):

Most of the data obtained from the Versar study and other surveys or contacts on charges for hauling, treatment, and disposal of hazardous wastes were of a general nature. The charges for hauling, treatment and disposal were mostly expressed on a cost/unit volume of waste basis. Because of the general nature of the data and lack of specific information on the waste characteristics, there was no reliable method for converting data on cost/unit volume of waste to data on cost/unit weight of waste, cost/unit weight of product, or cost/unit area product processed. These same comments generally apply to cost data for the several landfills (presented later in the cost section) where costs were usually expressed as cost/metric ton of waste. Because of the lack of specific information on the wastes, it was not possible to reliably convert data on cost/unit weight of waste to data on cost/unit weight of product or cost/unit area product processed.

The relationship between cost/unit volume of waste and cost/unit weight of waste or cost/unit area of product processed, which was developed from model plant data for the treatment and disposal of electroplating and metal finishing wastes, is presented and discussed in the latter part of the cost section of this report.

TABLE 50. CONTRACTOR CHARGES FOR WASTE HANDLING AND DISPOSAL[(a)]

Location	Wastes[(b)]		Service Fee For Handling[(c)]						Ultimate Disposal Facility	
			Hauling		Treatment and Disposal		Combined			
	Sludges	Liquids	Metric Units	Equivalent Units	Metric Units	Equivalent Units	Metric Units	Equivalent Units	Land-fill	Other
California	--	H/T/D	--	--	0.53¢/liter	2¢/gal	--	--	X	--
California	--	H/T/D	--	--	--	--	0.66¢/liter	2.5¢/gal	--	Ponding, Drum Burial Incineration
California	T/D	T/D	--	--	--	--	0.44¢/liter	70¢/bbl. (42 gal)	X	--
Connecticut	H/T/D	H/T/D					4.0¢/liter	15¢/gal	--	Land Stockpile
Delaware	H/T/D	H/T/D	0.26¢/liter per 161 km	1¢/gal per 100 mi.	2.6-5.3¢/liter	10-20¢/gal	--	--	X	Ocean Dump
Idaho	D	D	--	--	3.5¢/liter	$1.00/cu.ft.	--	--	--	Old Missle Silo
Illinois	H/D	H/T/D	--	--	--	--	4.0-5.3¢/liter	15-20¢/gal	X	Shipped Outside
Illinois	--	H	0.79¢/liter	3¢/gal	1.6¢/liter	6¢/gal	2.8¢/liter	9¢/gal	--	Trucked Outside
Illinois	T/D	T/D	--	--	--	--	0.8-1.9¢/liter	3-7¢/gal	X	--
Indiana	T/D	T/D	--	--	--	--	0.8¢/liter CN^- 2.6¢/liter	3¢/gal CN^- 10¢/gal	X	Deep Well Injection
Kentucky	H/D	H/D	$0.62/km per truck	$1.00/mi per truck	4.4¢/liter	$1.25/cu.ft.	--	--	--	Land Burial
Michigan	H/T/D	H/T/D	--	--	--	--	2.6-5.3¢/liter CN^- 10.6¢/liter	10-20¢/gal CN^- 40¢/gal	X	--
Michigan	H/T	H/T	--	--	--	--	CN^- $2.65/kg CrO_3 35¢/kg	CN^- $1.20/lb CrO_3 16¢/lb	--	Sewer
Ohio	--	T	--	--	CN^- $5.55/kg Cr^{+6} $2.76/kg plus 1.3¢/liter	CN^- $2.50/lb Cr^{+6} $1.25/lb plus 5¢/gal	--	--	--	Piped to Municipal Water Treatment Plant
Oklahoma	D	H/T/D	--	--	0.6¢/liter	2.3¢/gal	2.0-3.4¢/liter	7.5-13¢/gal	X	Deep Well Injection
Texas	D	H/T/D	--	--	--	--	CN^- 13-40¢/liter 1.8-7.9¢/liter otherwise	CN^- $0.48-1.51/gal 7-30¢/gal otherwise	X	--
Texas	T/D	T/D	--	--	--	--	≈5.0¢/liter	≈19¢/gal	X	Deep Well Injection
Washington	--	H/D	--	--	--	--	0.7¢/liter	2.5¢/gal	X	Ponding, Drum Burial

(a) Data were derived from a survey dated August 1974, of waste management facilities, made by Versar, Inc. for Hazardous Waste Management Division, Office of Solid Waste Management Programs, Environmental Protection Agency, Washington, D.C. As the survey was made during the first half of 1974, the cost data were considered to correspond closely enough to December 1973 values, so that no adjustment of costs were made.

(b) H = Hauling; T = Treatment; D = Disposal

(c) CN^- represents cyanides, and CrO_3 represents chromates.

Treatment and Disposal.* Table 50 shows that for "Treatment and Disposal" the fee structure is somewhat more complicated. Mileage rates are no longer apparent, but the data suggest some firms are giving more serious consideration to toxic versus unspecified wastes. For example, an Ohio firm charges 1.3¢ per liter (5¢ per gallon) of waste plus $5.51 per kilogram ($2.50 per pound) of cyanide (CN^-) handled and $2.76 per kilogram ($1.25 per pound) of hexavalent chromium handled. This seems to be independent of the concentrations of cyanide and hexavalent chromium in the materials accommodated.

For the most part, though, "Treatment and Disposal" fees seem independent of the waste's toxicity and range from 0.53 to 5.38¢ per liter (2 to 20¢ per gallon) with an average of about 2.4¢ per liter (9¢ per gallon).

Combined.* Most contractor firms seemed to prefer and charge a flat fee for "Hauling" plus "Treatment and Disposal" of the wastes as opposed to separating the two operations. The firms surveyed also seemed to place more emphasis on special charges for toxic wastes. For cyanide wastes, the fees ranged from 2.6 to 40.0¢ per liter (10¢ to $1.51 per gallon); no specific concentration of cyanide was indicated. One firm charges $2.65 per kilogram ($1.20 per pound) of cyanide sludge. Given this wide range of variations, the average fee is estimated to be around 13.2¢ per liter (50¢ per gallon) for cyanide wastes. The information is inadequate to show that the variations are solely due to the special toxic charge. One company in Michigan charges 35¢ per kilogram (16¢ per pound) of CrO_3. However, a firm in Ohio charges $2.76 per kilogram ($1.25 per pound) of Cr^{+6} for "Treatment and Disposal" alone. Part of this apparent inconsistency can be resolved by the fact that the fee is based on CrO_3 in one case and on Cr^{+6} in the other. Another possible reason for the difference in fees could be the type and cost of the reducing materials employed. However, in general, there is not enough information to permit more explicit statements on the different fees charged.

In general, the fee for "Combined" waste handling ranged from 0.8 to 7.9¢ per liter (3 to 30¢ per gallon), when toxic substances were not specifically identified. The average fee was about 2.9¢ per liter (11¢ per gallon). A summary of the average waste handling fees is shown in Table 51. The average charge for handling toxic wastes such as hexavalent chromium or cyanide ranged from $2.71 to $5.51/kg or $1.25 to $2.50 /lb.

BCL and NAMF Survey Data on Contractor Waste Handling Charges

As had been indicated earlier in the report, BCL conducted a telephone and plant visit survey of the treatment and disposal contractors. Information was also obtained from those electroplating and metal finishing facilities on waste contractors and their charges. Data and results of these surveys are presented above (Table 50 and accompanying text). Based on the BCL telephone and plant visit survey data, the average hauling

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** See footnote on page 154.

TABLE 51. SUMMARY OF AVERAGE WASTE HANDLING FEES[a]

Waste or Waste Handling Activity	Average Fee Charged: Metric Units	Average Fee Charged: Equivalent Units
A. Nonspecific Waste		
Hauling	0.53¢/liter[b]	2¢/gal[b]
Treatment and Disposal	2.3¢/liter	8.6¢/gal
Combined Hauling-Treatment-Disposal	2.9¢/liter	11¢/gal
B. Toxic Waste[c]	\$2.71 to \$5.51/kg[d]	\$1.25 to \$2.50/lb[d]

(a) Data were derived from Versar, Inc. survey for EPA cited in Table 50.

(b) An additional mileage fee may also be charged.

(c) This usually refers to chromium and/or cyanide wastes.

(d) The charge generally refers to a kilogram or pound of chromium and/or cyanide independent of overall waste character or volume. An additional fee per unit volume of waste handled may also be charged.

(including collection) cost was estimated at about 2.6¢ per liter (10¢ per gallon), and the combined collection-treatment-disposal cost averaged 5.8¢ per liter (22¢ per gallon). The average service cost for combined hauling-treatment-disposal, as determined from the NAMF questionnaire survey of electroplaters and metal finishes, was 3.7¢ per liter (14¢ per gallon).

The charges, as determined by the Versar, Inc. survey, the BCL telephone and plant visit survey, and the NAMF survey of electroplaters, were considered to be representative of fees being paid by the electroplating and metal finishing industry to waste treatment and disposal contractors. Accordingly, the data from the three surveys were averaged and adjusted to December, 1973, prices as shown in Table 52. The contractor charges from the BCL telephone and plant visit survey and the NAMF survey were adjusted as indicated in Footnote (b) in Table 52. The average contractor charges for hauling (which includes collection) was 1.3¢ per liter (5¢ per gallon), while the average charge for the combined hauling-treatment-disposal was 3.6¢ per liter (13.6¢ per gallon). These charges were considered to be representative of the Level I technology for disposal in simple or municipal landfill.

Sludge Handling-Disposal Costs from Industry Responses

A survey by means of the NAMF questionnaire was conducted to obtain data on sludge handling and disposal costs and also on the levels of treatment technology employed. Level I technology generally involves handling of sludges containing 5 percent or less solids and disposal of these sludges in a simple or municipal landfill. Level II technology consists of dewatering the water pollution control (WPC) sludges to increase the solids content to about 20 percent, plus disposal of the WPC sludge and other wastes in an approved landfill site. Among the electroplating and metal finishing facilities responding to the NAMF questionnaire, only nine plants provided cost data on sludge dewatering to about 20 percent solids. Sludge dewatering was generally achieved using centrifuges or vacuum filters. Four of the nine plants definitely had their sludges hauled away by a contractor for disposal in a landfill, which most likely corresponded to that of Level I technology. The cost data obtained from these nine case studies are summarized in Table 53.

The unit costs for treatment and disposal varied from $0.021 to $0.40 per liter ($0.08 to $1.51 per gallon), with generally lower unit operating costs with the larger capacity systems as shown in Figure 8. The available data are inadequate to establish a definitive capacity-cost relationship. Accordingly, the model plants were used to provide definitive cost-capacity relationships for the treatment and disposition of electroplating and metal finishing wastes. Detailed costs for the nine case studies covered in Table 53 are presented in Appendix F. Additional data on such items as plating rate, number of plant employees, sales volume, amount of sludge, and waste treatment and disposal cost for the 44 industry responses are presented in Appendix G. The nine case studies discussed above were selected from the 44 responses. Because of the wide scatter of the industry response data (as can be seen from the plots shown in Figures G-1 to G-7 in Appendix G), the data derived from the model plants were used

TABLE 52. SUMMARY OF CONTRACTOR WASTE HANDLING CHARGES

Source	Hauling Charge, (Adjusted to 1973 Prices)[a,b]		Combined Hauling-Treatment-Disposal Charge, (Adjusted to 1973 Prices)[a,b]	
	c/liter	c/gallon	c/liter	c/gallon
Versar Inc. Survey for EPA[a]	0.53	2.0	2.9	11
BCL Telephone and Visit Survey[b]	2.1	8.0	4.7	17.8
NAMF Survey of Electroplaters and Metal Finishers[b]	N.A.[c]	N.A.[c]	3.1	11.9
Average Charge	1.3	5.0	3.6	13.6

(a) The Versar survey was made during the first half of 1974, and the charges were considered equivalent to the December 1973 prices.

(b) The BCL telephone and plant visit survey data were gathered mostly during the December, 1974 - January, 1975, period, while the NAMF survey was conducted during the 4th quarter of 1974. Accordingly, the actual charges obtained from the two surveys were adjusted (lowered) using the Marshall and Stevens (M&S) Index factors of 350/430 and 350/413, respectively. (Reference: M&S Equipment Cost Index, Chemical Engineering, Vol 82, No. 18, September 1, 1975, p 168).

(c) N.A. = not available

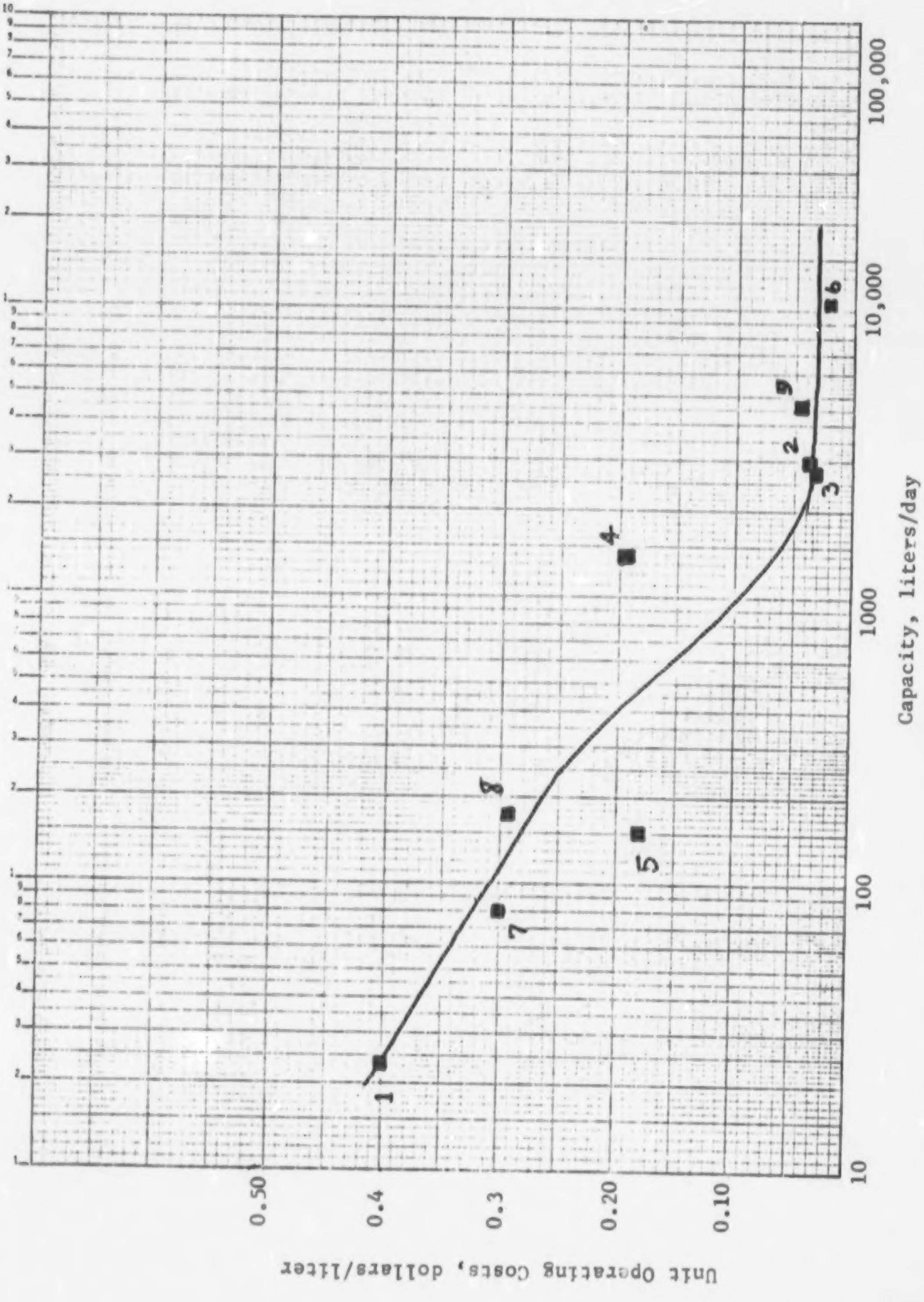

FIGURE 8. COST-CAPACITY RELATIONSHIP FOR SLUDGE DEWATERING AND DISPOSAL SYSTEMS

TABLE 53. SUMMARY COST DATA FOR SLUDGE DEWATERING AND DISPOSAL SYSTEMS[a]

Case Study	System Characteristics	Volume of Sludge Handled		Capital Cost (Dollars)	Unit Capital Cost		Operating Cost $/Year	Unit Operating[a] Cost	
		liter/day	gal/day		$/liter/day	$/gal/day		$/liter	$/gal
1. California 333	4-stage Clarifier, Contractor Hauling	23.8	63	6,475	271.54	1,027.79	2,068	0.40	1.51
2. California 3199	Vacuum Filter, and Contractor Hauling to Landfill	2,960	782	32,500	10.98	41.56	25,016	0.037	0.14
3. Illinois 3022	Filter, and Landfill Disposal	2,774	733	9,196	3.32	12.55	21,142	0.032	0.12
4. Indiana D	Filter Press, and Landfill Disposal	1,378	364	226,000	164.03	620.88	67,400	0.196	0.74
5. Indiana E	Clarifier, Centrifuge, Dewatering, Landfill Disposal	151	40	31,760	209.78	794.00	6,777	0.180	0.68
6. Iowa M	Vacuum Precoat Filter, Landfill Disposal	10,447	2,760	270,336	25.88	97.96	57,413	0.021	0.08
7. Massachusetts	Centrifuge, Landfill Disposal	80	21	14,700	184.94	699.99	5,970	0.301	1.14
8. Michigan K	Rotary Vacuum Filter, Contractor Hauling	174	46	30,102	174.75	661.43	13,225	0.293	1.11
9. Minnesota N	Dewater, Contractor Hauling	4,686	1,238	33,138	70.70	26.76	53,400	0.045	0.17

(a) Unit operating costs were based on a 250-day year, if the number of operating days per year was not provided.

to develop the relationships between waste treatment and disposal costs and items such as area processed, sludge amount, plant size, etc., which are presented later in the main body of the report.

Costs of Landfill Disposal

In order to estimate the additional cost that contractors would charge for an approved sanitary landfill, it was necessary to determine the representative operating costs for a simple or municipal sanitary landfill operation. Aside from the sludge dewatering, the most important difference affecting the overall waste treatment and disposal costs is the landfill cost. Considerable data on how landfill costs vary with the size of the operation and site characteristics are presented below.

Table 54 provides a range of fixed landfill costs for three sites ranging in capacity from 27 to 544 metric tons per day (30 to 600 tons per day).* Additional data on the areas and overall fill capacities for the three sites are given in the footnotes to the table. It should be noted that there is considerable spread in the individual and total costs for the three sites. For example, the total unit costs ranged from $0.84 to $1.94 per metric ton ($0.76 to $1.76 per ton) and the range was even greater for the individual unit costs for the three sites because of their dependence on the particular site characteristics.

The principal operating-cost items for sanitary landfills such as those cited immediately above are:

(1) Personnel
(2) Equipment
    (a) Operating expenses -- gas, oil, etc.
    (b) Maintenance and repair
    (c) Rental, depreciation, or amortization
(3) Cover material -- material and transportation
(4) Administration and overhead
(5) Miscellaneous tools, utilities, insurance, maintenance to roads, fences, facilities, drainage features, etc.

The operating costs (land excluded) for Sites 1, 2, and 3 were about $1.92, $2.76, and $1.49 per metric ton ($1.75, $2.50, and $1.35 per ton), respectively.* The average operating costs for landfills in metropolitan Washington, D.C. were indicated to be about $3.03 per metric ton ($2.75 per ton).*

Figure 9 presents a range of capital and operation-maintenance (O&M) costs (excluding land costs) for sanitary landfills in the Minneapolis, Minnesota, area for 1972.*,** Quantities are expressed in tons of net sludge cake per day. As can be seen from Figure 9, the curves of the

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* See Table 40, Footnote (a) for reference.

** "Process Design Manual for Sludge Treatment and Disposal", U. S. EPA, EPA 625/1-74-006, Washington, D.C., October, 1974.

TABLE 54. INITIAL COSTS FOR THREE SANITARY LANDFILLS OF DIFFERENT CAPACITIES, 1973(a,b)

Item	Site 1(c) 27.2 Metric Tons/Day (30 Tons/Day)			Site 2(d) 453.6 Metric Tons/Day (500 Tons/Day)			Site 3(e) 544.3 Metric Tons/Day (600 Tons/Day)		
	Cost, (thousands of dollars)	Cost per Metric Ton, ($)	Cost per Ton, ($)	Cost, (thousands of dollars)	Cost per Metric Ton, ($)	Cost per Ton, ($)	Cost, (thousands of dollars)	Cost per Metric Ton, ($)	Cost per Ton, ($)
Planning and Design	3	0.033	0.03	(f)	(f)	(f)	90	0.209	0.19
Site Development	22	0.242	0.22	430	0.176	0.16	400	0.926	0.84
Facilities	14	0.154	0.14	150	0.066	0.06	100	0.231	0.21
Equipment(g)	50	1.378	1.25	350	0.595	0.54	246	0.573	0.52
Total	89	1.81	1.64	930	0.84	0.76	836	1.94	1.76

(a) Reference: Decision Makers Guide in Solid Waste Management, U.S. Environmental Protection Agency, U.S. Government Printing Office, Washington, D.C., 1974.

(b) It was indicated that land costs can vary over a large range and depend on local conditions. In most instances, the initial investment for land can be recovered on completion of the sanitary landfill through subsequent development or use of the land.

(c) It is located in a rural Southern location. The calculated (by BCL) site capacity was 90,720 metric tons (100,000 tons). The operating costs incurred at the site were about $1.92 per metric ton ($1.75 per ton). The cost of land was excluded from the operating costs for the site; this same comment applies to Sites 2 and 3.

(d) Site 2 is on a Southeastern 1500-acre tract which required $430,000 in development costs for special construction for ground water protection. The calculated capacity of the site was about 2,358,720 metric tons (2,600,000 tons). The operating costs incurred at this site were about $2.76 per metric ton ($2.50 per ton).

(e) Site 3 is a 50-acre tract in a Midwest urban location, with an indicated capacity of 430,920 metric tons (475,000 tons). The operating costs incurred at this site were $1.49 per metric ton ($1.35 per ton).

Table 54 Footnotes (Continued)

(f) Cost data were not available.

(g) Equipment cost was calculated on the basis of a 5-year replacement cycle and then related to total site capacity.

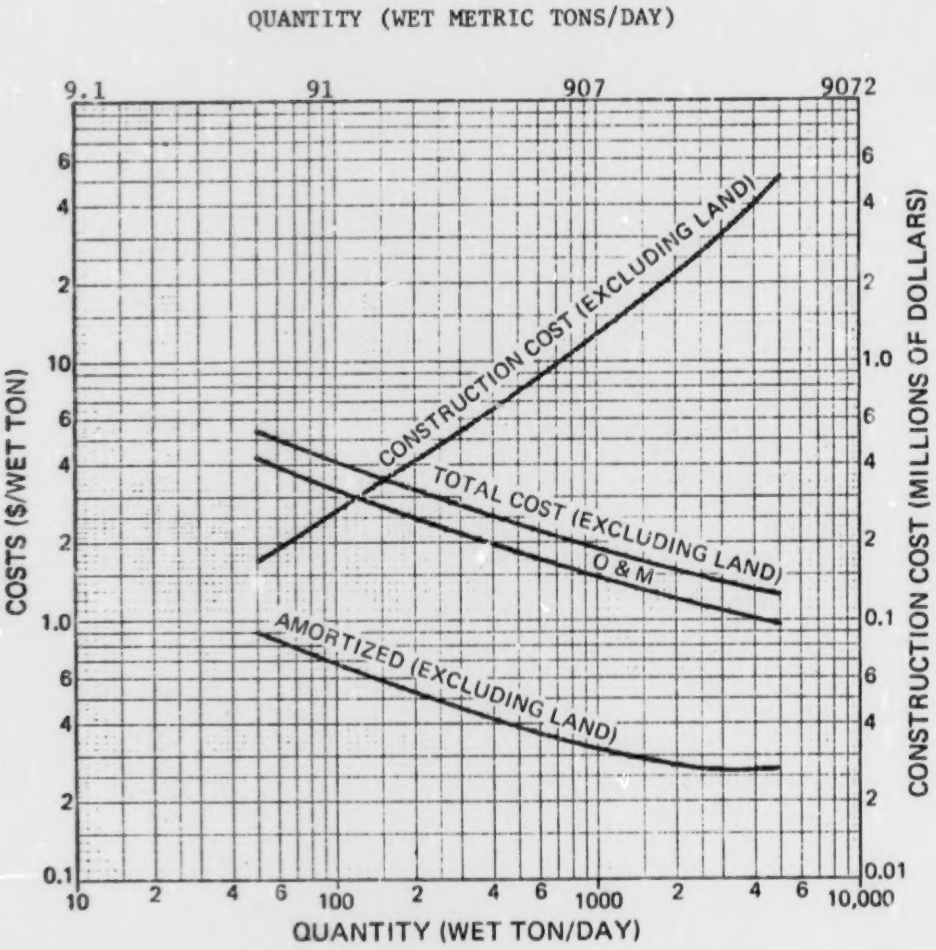

FIGURE 9. CAPITAL AND O/M COSTS FOR SANITARY LANDFILLS[a,b,c]

NOTES:

1. Minneapolis, Mar., 1972. ENR Construction Cost Index of 1827.
2. Amortization of 7% for 20 years.
3. Labor rate of $6.25 per hour.
4. Quantity assumes 6-day work week.
5. Wet sludge must be considered for cost per ton.
6. Source: U. S. P. H. S. and Stanley Consultants.

(a) Stanley Engineers, "Sludge Handling and Disposal, Phase I, State of the Art", Report to Metro Sewer Board of Twin Cities Area, November 15, 1972.

(b) "Process Design Manual For Sludge Treatment and Disposal", U.S. EPA, EPA 625/1-74-006, Washington, D.C., October, 1974.

(c) Burd, R. S., "A Study of Sludge Handling and Disposal", Report for FWPCA, Department of the Interior, by the Dow Chemical Company, Publication WP-20-4 (May 1968).

total cost (excluding land) and O&M costs versus quantity of wet cake per day were almost straight lines in a log-log plot. The O&M costs varied from about $1.10 to $4.40 per metric ton ($1 to $4 per ton) of wet cake, depending upon the size of the landfill operation. Other investigators have reported landfill costs (1968) from $1.10 to $4.40 per metric ton ($1 to $4 per ton) of dry solids.*,**

Figure 10 shows a range of operating costs (1970 values) to be expected as a function of the size of the sanitary landfill operation. Some economies of scale accrue in the size range from 0 to about 182,000 metric tons (0 to 2000,000 tons) per year. Beyond 182,000 metric tons (200,000 tons) per year, the unit operating costs seem rather stable. Figure 11 presents data somewhat similar to that shown in Figure 10, but supplies additional detail. For instance, in addition to minimums, maximums, and averages, Figure 11 suggests the nature of the cost differences to be expected for different landfill operations, based on the characteristics of the sites and the equipment employed (1969 values).

In summation, based on the data from various sources presented above, the estimated operating and maintenance costs for sanitary landfills range from about $1.10 to $5.50 per metric ton ($1 to $5 per ton). In some instances, there may be an additional estimated capital cost (excluding land) in site development, facilities, etc. of about $0.44 to $1.55 per metric ton ($0.40 to $1.50 per ton).

Sanitary Landfill Fees

Estimation of Costs for A Simple or Municipal Landfill

According to the Versar, Inc. survey and BCL contacts, the Los Angeles County Class I disposal sites will take almost any liquid or solid waste; there are no treatment facilities. Liquid wastes are generally mixed in with the refuse. The charges for hazardous wastes are usually the same as for nonhazardous materials. Table 55 shows the fees charged by several of the Los Angeles County landfills for different types of wastes. The rates shown in the table had been in effect from 1970 to 1972, and were scheduled for increases as indicated in Footnote (a) of Table 55 in July, 1974. Accordingly, because of the long period of time between rate increases at the site, the proposed July, 1974, fees were considered for this report to be representative of December, 1973, charges.

Assuming bulk-density values ranging from 1.10 g/cc to 1.4 g/cc for the electroplating and metal finishing wastes, the landfill charges on a volumetric basis (at $3.31 per metric ton of liquid wastes) are tabulated below:

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* "Process Design Manual for Sludge Treatment and Disposal", U. S. EPA, EPA 625/1-74-006, Washington, D.C., October, 1974.

** Burd, R. S., "A Study of Sludge Handling and Disposal", Report for FWPCA, Dept. of the Interior, by the Dow Chemical Co., Publ. WP-ZO-4 (May, 1968).

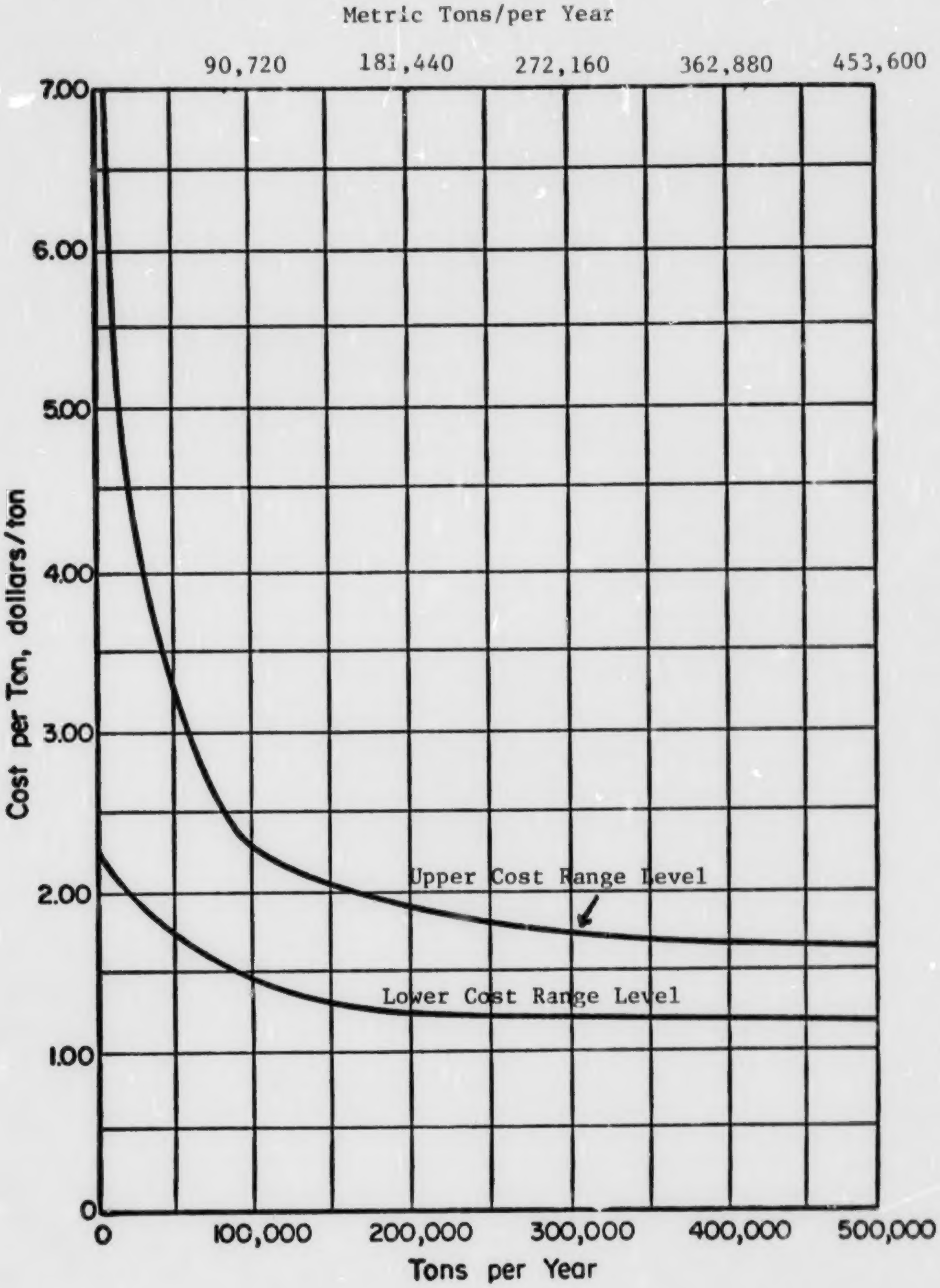
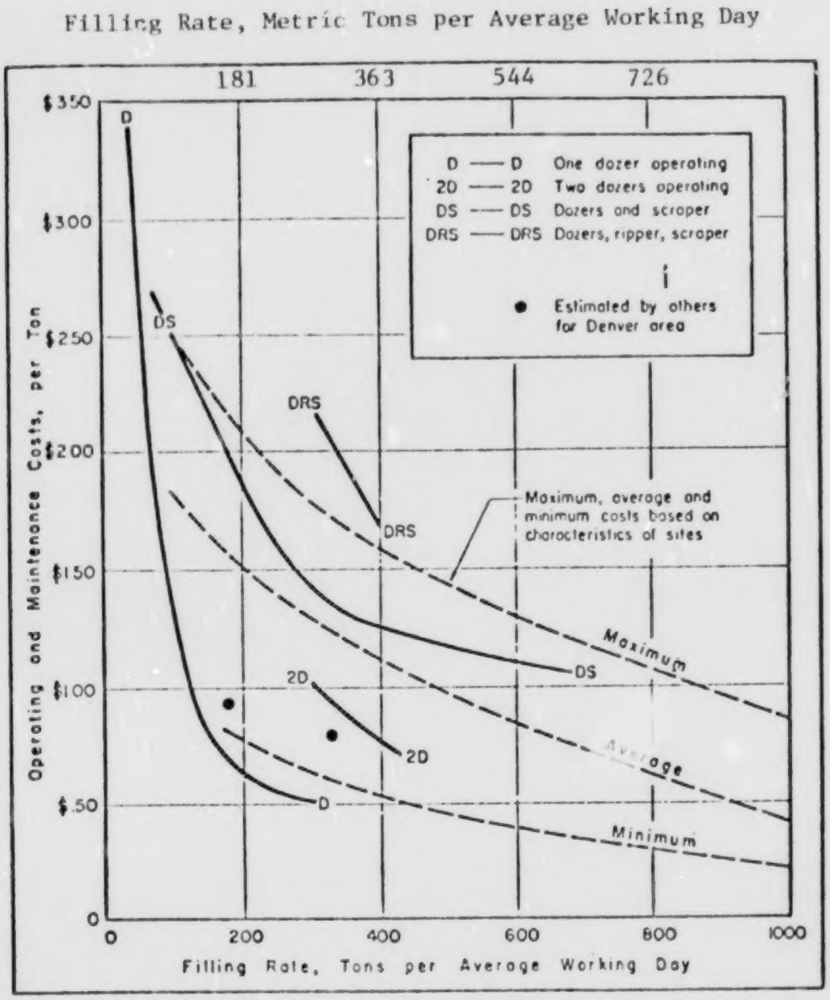


FIGURE 10. RANGE OF SANITARY LANDFILL OPERATING COSTS(a,b)

(a) Reference: Updated from "Sanitary Landfill Facts", Thomas J. Sorg and H. Lanier Hickman, Jr., 1970, PHS Publication No. 1792.

(b) Based on 6-day work week.



Note: Chart shows how cost of ownership and operation of equipment relates to the required filling rate.

FIGURE 11. ESTIMATED SANITARY LANDFILL OPERATION AND MAINTENANCE COSTS(a)

(a) Reference: Public Works, 100 (3):79, March 1969, as cited by: Bond, R. G., Straub, C. P., and Prober, R., editors, Handbook of Environmental Control, Volume II, Solid Waste, CRC Press, Cleveland, 1973.

TABLE 55. FEES CHARGED BY LOS ANGELES CLASS I DISPOSAL SITES
FEE SCHEDULE 1970-72 TO JULY 1974 [(a)]

	Hard-to-Handle Bulky Materials		Liquid Wastes		Refuse	
	Cost per Metric Ton, Dollars,	Cost per Ton, Dollars	Cost per Metric Ton, Dollars,	Cost per Ton, Dollars	Cost per Metric Ton, Dollars,	Cost per Ton, Dollars
Palos Verdes Landfill No. 1	3.31	3.00	2.20	2.00	2.20	2.00
Spadra Landfill No. 2	2.76	2.50	1.76	1.60	1.76	1.60
Calabasas Landfill No. 5	2.76	2.50	1.76	1.60	1.76	1.60
Puentes Hills Landfill No. 6	3.31	2.50	1.76	1.60	1.76	1.60

(a) Proposed rate changes for the L.A. Sanitation Districts disposal facilities scheduled to become effectiv July 1, 1974 raised the rates at all sites as shown below:

Hard-to-handle, bulky materials: \$3.31 per metric ton (\$3.00 per ton)
Liquid wastes: \$3.31 per metric ton (\$3.00 per ton)
Refuse: \$2.20 per metric ton (\$2.00 per ton).

Electroplating and Metal Finishing Wastes	Landfill Charge cents/liter	Landfill Charge cents/gal
Waste - (Bulk density 1.1 g/cc)	0.36	1.38
Waste - (Bulk density 1.3 g/cc)	0.43	1.63
Waste - (Bulk density 1.4 g/cc)	0.46	1.75

Based on the Los Angeles County landfill fees (which are considered low) and the estimated capital and operating costs for landfills cited earlier, it was estimated that 0.8¢ per liter (3.0¢ per gal) would be representative of nationwide landfill fees paid by the contractors who handle wastes produced by the electroplating and metal finishing industry for disposal in a simple or municipal sanitary landfill.

Estimation of Level II Technology Landfill Fees

The best technology currently employed, that was identified by the BCL survey and discussions with electroplaters, waste-handling contractors, and government (national, state, county, etc.) personnel for the disposal of electroplating and metal finishing wastes, was represented by the disposal of the potentially hazardous wastes in an approved sanitary landfill. One of the sites that was identified was the Ventura County (California) landfill.

The Ventura hazardous waste landfill site was selected with special care and has a clay-type soil. Some of the features of the approved Ventura sanitary landfill operation are as follows:

(a) Site geology, hydrology, and monitoring meet all State requirements for Class I landfills.

(b) Waste burial is mapped; a grid of prior disposal is maintained to avoid undesirable mixing interactions.

(c) Contents of waste streams are determined and screened for acceptability before disposal.

(d) All site run-off is collected.

(e) Liquid wastes are mixed with soil rather than indiscriminate refuse.

(f) Special attention is given to disposal of hazardous wastes by landfill personnel.

The charge for the Ventura landfill is $8.45 per metric ton of waste ($7.70 per ton) plus $1.00 for the first 0.9 metric ton ($1.00 per ton) and $0.66 on each additional metric ton ($0.60 per ton). There is also a $25.00 application fee charged to the hauler for each new waste received (fee covers chemical analyses and other administrative costs). The combined charges amount to about $9.25 per metric ton ($8.40 per ton) of waste. For a waste with a bulk density of 1.3 g/cc, the landfill charge on a volumetric basis amounts to about 1.2¢ per liter (4.54¢ per gallon).

The ratio of the Ventura landfill charge to the Los Angeles County landfill charge for a waste of bulk density of 1.3 g/cc is 1.20/0.43 or 2.8. Assuming that the overall landfill charges nationwide for a simple or municipal landfill are about 0.8¢ per liter (3.0¢ per gal), a representative charge for an approved sanitary landfill disposal site would be about 2.8 times greater or 2.24¢ per liter (8.4¢ per gal). Thus a premium cost of about 1.44¢ per liter (5.4¢ per gal) should be added to the combined contractor hauling-treatment-disposal charge of 3.6¢ per liter (13.6¢ per gal) for a simple or municipal landfill to give a combined contractor charge of about 5.0¢ per liter (19.0¢ per gal) for an approved landfill.

Estimation of Costs for a Secured Sanitary Landfill

The proposed disposal facilities that are planned by Chem-Trol Pollution Services, Inc. at Model City (Lewiston) N.Y. (based on the Versar Inc. survey data) were considered to be representative of a secured sanitary landfill operation. Wastes will be disposed of on a tightly controlled landfill on Chem-Trol property. The site chosen has a highly impervious clay base. The landfill will be fully lined with PVC, and an inner layer of clay will be used to mechanically protect the plastic liner. The location of all landfilled wastes will be documented in the event recovery or additional treatment is required at some future time. The landfill construction includes a sump for drainage and leachate collection. The contents of the sump will be analyzed for leachate and if needed the sump contents pumped to the waste-treatment facility. The treated effluent will be discharged to either a sewer or stream, and the solid residues returned to the landfill.

The charges for the disposal of sludges at the Chem-Trol site were estimated to be about 6.9¢ per liter (26¢ per gal). Thus the total charge [allowing a 1.32¢ per liter (5.0¢ per gal) charge for hauling] for overall hauling, treatment, and disposal of electroplating and metal finishing waste sludges (20 percent solids) in a secured sanitary landfill would be about 8.2¢ per liter (31¢ per gal).

Summary of Contractor Charges for Hauling, Treatment, and Landfill Disposal of Wastes at Different Sites

A summary of contractor hauling, treatment, and disposal charges for a simple or municipal sanitary landfill, an approved sanitary landfill, and a secured sanitary landfill for electroplating and metal finishing wastes (destined for land disposal) is presented in Table 56.

TABLE 56. SUMMARY OF ESTIMATED CONTRACTOR HAULING, TREATMENT, AND DISPOSAL CHARGES FOR ELECTROPLATING AND METAL FINISHING WASTE DESTINED FOR LAND DISPOSAL

Treatment Technology	Hauling Charge[a]		Contractor Charge For Combined Hauling, Treatment and Disposal[b]		Contractor Charge for Treatment and Disposal[c]		Total Contractor Charge to the Electroplater	
	¢ per liter	¢ per gal	¢ per liter	¢ per gal	¢ per liter	¢ per gal	¢ per liter	¢ per gal
Simple or Municipal Landfill	1.32	5.0	3.6	13.6	-	-	3.6	13.6
Approved Landfill	1.32	5.0	5.0	19.0	-	-	5.0	19.0
Secured Landfill	1.32	5.0	-	-	6.9	26.0	8.2	31.0

(a) This is the charge made by the contractor for collecting and hauling the waste to the disposal site.

(b) This represents the charge made by the contractor to the electroplater for combined hauling, treatment (if any), and disposal in a landfill. The charge includes landfill fees.

(c) This is the charge for treatment and disposal of the waste after delivery to the disposal site.

These charges were used to generate the waste hauling, treatment, and disposal costs for the model plants and also to project the nationwide costs for the years 1975, 1977, and 1983 (expressed in December, 1973, dollars) for treatment and disposal of electroplating and metal finishing wastes.

Capital and Operating Costs for Waste Treatment and Disposal at Three Technology Levels for Three Model Plants

Introduction

The estimated investment and annual operating costs for the overall treatment and disposal of potentially hazardous wastes destined for disposal on land at the three technology levels for three model plants are shown in Table 57. Detailed descriptions of the electroplating and metal finishing operations carried out in the 16-man, 38-man, and 87-man plants are presented in Appendixes B, C, and D, respectively. Data on workpiece-area processed, and also on the type and quantity of different wastes generated in the model plants are also presented in these appendixes.

Water Pollution Control (WPC) Sludges

For Level I Technology for the model plants, the water pollution control (WPC) sludge containing 5 percent solids was assumed to have been produced by the use of clarifiers and/or settling tanks. The production of the 5 percent solids sludge was considered to have been part of the wastewater treatment operation and its costs. The 5 percent sludge was assumed to be essentially free of cyanides, hexavalent chromium, or other wastes requiring special treatment. The principal item of equipment involved with this sludge at the electroplating and metal finishing plants is the storage vessel.

For Level II and III technologies for the model plants, the WPC stream underflow from a clarifier containing 2 percent solids was dewatered to a 20 percent sludge with a centrifuge. The production of the 2 percent solids underflow was considered to be part of the wastewater treatment operation and its costs. Dewatering to produce the 20 percent solids sludge was considered to be part of the sludge handling and disposal cost.

Centrifuge Size and Cost Calculations

The calculations used to determine the size of the centrifuge needed for producing the 20 percent sludge is illustrated using data from the 38-man model plant.

From Table 35 and data on the wastewater treatment presented in

Appendix C, the quantity (dry weight) of metal hydroxides and other precipitates or solids in the water pollution control sludge (20 percent solids) is 35,000 kg/year or 140 kg/day. The bulk density of the solids in the WPC sludge was estimated to be 2.8 kg/liter.

The total weight of the sludge (20 percent solids) was calculated as follows:

$$\frac{140 \text{ kg/day}}{0.20} = 700 \text{ kg/day} .$$

The sludge consists of:

150 kg/day solids
560 kg/day water.

The volumes occupied bv the solids and water portions of the sludge, respectively, are as follows:

$$\frac{140 \text{ kg/day}}{2.8 \text{ kg/liter}} = 50 \text{ liters/day solids}$$

$$\frac{560 \text{ kg/day}}{1.0 \text{ kg/liter}} = 560 \text{ liters/day water.}$$

The total volume of the 20 percent solid sludge produced by the centrifuge is:

$$50 + 560 = 610 \text{ liters/day } (161.2 \text{ gal/day}).$$

The bulk density of the 20 percent sludge was calculated to be 1.15 g/cc.

The volume of 2 percent solids underflow that has to be centrifuged daily was calculated as follows:

$$\frac{140 \text{ kg/day}}{0.02} = 7000 \text{ kg/day}$$

$$\text{Volume of solids} = 50 \text{ liters/day}$$

$$\text{Weight of solids} = 50 \times 2.8 = 140 \text{ kg/day}$$

$$\text{Volume of water} = \frac{7000 \text{ kg/day} - 140 \text{ kg/day}}{1 \text{ kg/liter}} =$$

$$6860 \text{ liters/day}$$

$$\text{Total Volume} = 6860 + 50 = 6910 \text{ liters/day}$$

or 1826 gal/day.

TABLE 57. DETERMINATION OF ESTIMATED CAPITAL AND OPERATING COSTS FOR WASTE HANDLING AND DISPOSAL AT

			Annual Amount of Waste Material[c]		Capital Investment in Equipment			Annual Depreciation Cost (at 10% of Cap. Inv.)[e],
					Installed Centrifuge System	Waste Storage Vessel		
Model Plant	Technology Treatment Level	Waste Stream[b]	m^3	Metric Ton	Cost[d], $	Capacity, m^3	Cost, $	$
16-Man	I	WPC Sludge (5% Solids, BD[b] 1,033 g/cc)	295	304.7	None	28	3,100	310
		Process Wastes (BD 1.5 g/cc)	8.1	12.15	-	1.7	600	60
		Degreaser Solvent Sludge (BD 1.5 g/cc)	1.4	2.10	-	0.9	400	40
		Combined Waste Streams	305	319.0	-	-	4,100	410
16-Man	II	WPC Sludge (20% Sol., BD 1.15 g/cc)	66.3	76.25	7,150	7.1	1,200	835
		Process Wastes (BD 1.5 g/cc)	8.1	12.15	-	1.7	600	60
		Degreaser Solvent Sludge (BD 1.5 g/cc)	1.4	2.10	-	0.9	400	40
		Combined Waste Streams	76	90.50	7,150	-	2,200	935
16-Man	III	WPC Sludge (20% Sol., BD 1.15 g/cc)	66.3	76.25	7,150	7.1	1,200	835
		Process Wastes (BD 1.5 g/cc)	8.1	12.15	-	1.7	600	60
		Degreaser Solvent Sludge (BD 1.5 g/cc)	1.4	2.10	-	0.9	400	40
		Combined Waste Streams	76	90.50	7,150	-	2,200	935
38-Man	I	WPC Sludge (5% Sol., BD 1,033 g/cc)	678	700.4	None	57	4,500	450
		Process Wastes (BD 1.5 g/cc)	16.9	25.35	-	3.4	800	80
		Degreaser Solvent Sludge (BD 1.5 g/cc)	2.4	3.60	-	1.4	500	50
		Electroless-Ni Sludge (BD 1.45 g/cc)	20.2	29.29	-	5.7	1,000	100
		Combined Waste Streams	718	758.6	-	-	6,800	680
38-Man	II	WPC Sludge (20% Sol., BD 1.15 g/cc)	153	176.0	19,500	14	1,800	2,130
		Process Wastes (BD 1.5 g/cc)	16.9	25.35	-	3.4	800	80
		Degreaser Solvent Sludge (BD 1.5 g/cc)	2.4	3.60	-	1.4	500	50
		Electroless-Ni Sludge (BD 1.45 g/cc)	20.2	29.29	-	5.7	1,000	100
		Combined Waste Streams	193	234.2	19,500	-	4,100	2,360
38-Man	III	WPS Sludge (20% Sol., BD 1.15 g/cc)	153	176.0	19,500	1.4	1,800	2,130
		Process Wastes (BD 1.5 g/cc)	16.9	25.35	-	3.4	800	80
		Degreaser Solvent Sludge (BD 1.5 g/cc)	2.4	3.60	-	1.4	500	50
		Electroless-Ni Sludge (BD 1.45 g/cc)	20.2	29.29	-	5.7	1,000	100
		Combined Waste Streams	193	234.2	19,500	-	4,100	2,360
87-Man	I	WPC Sludge (5% Sol., BD 1,033 g/cc)	1,569	1,620.8	None	142	7,900	790
		Process Wastes (BD 1.5 g/cc)	39.1	58.65	-	7.1	1,200	120
		Degreaser Solvent Sludge (BD 1.5 g/cc)	2.8	4.20	-	2.0	600	60
		Electroless-Ni Sludge (BD 1.45 g/cc)	20.2	29.29	-	5.7	1,000	100
		Combined Waste Streams	1,631	1,712.9	-	-	10,700	1,070
87-Man	II	WPC Sludge (20% Sol., BD 1.15 g/cc)	353	406.0	48,700	28	3,100	5,180
		Process Wastes (BD 1.5 g/cc)	39.1	58.65	-	7.1	1,200	120
		Degreaser Solvent Sludge (BD 1.5 g/cc)	2.8	4.20	-	2.0	600	60
		Electroless-Ni Sludge (BD 1.45 g/cc)	20.2	29.29	-	5.7	1,000	100
		Combined Waste Streams	415	498.1	48,700	-	5,900	5,460
87-Man	III	WPC Sludge (20% Sol., BD 1.15 g/cc)	353	406.0	48,700	28	3,100	5,180
		Process Wastes (BD 1.5 g/cc)	39.1	58	-	7.1	1,200	120
		Degreaser Solvent Sludge (BD 1.5 g/cc)	2.8	4.20	-	2.0	600	60
		Electroless-Ni Sludge (BD 1.45 g/cc)	20.2	29.20	-	5.7	1,000	100
		Combined Waste Streams	415	498.1	48,700	-	5,900	5,460

(a) The model plant operations were based on 250 working days per year. The descriptions and details of the various electroplating and coating operations, along with processing rates for the 16-man, 38-man, and 87-man model plants are presented in Appendices C, B, and D respectively. All costs are in December 1973 dollars.

(b) The BD (bulk density) of each of the four stream sludges was estimated taking into account the amounts and densities of different materials that make up the particular steam wastes.

(c) The volumes of waste material to be hauled away and disposed by the contractor were calculated using the bulk densities and the amounts of wastes generated in the model plants as shown in Table 31 (page 73).

(d) The procedures used to calculate the different sized centrifuges required in the model plants and also to estimate the installed cost of the overall centrifuge systems are illustrated in the text of this section of the report. The upper curve of Figure 13 shows the basic centrifuge unit costs in December 1973 dollars.

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THREE TECHNOLOGY LEVELS FOR THREE DIFFERENT SIZED ELECTROPLATING AND METAL FINISHING MODEL PLANTS[a]

Annual Interest Cost (at 10% of Cap. Inv.)(e), $	Annual Labor Cost (at $8/Hr), $	Annual Power Cost (at 2¢/Kwhr), $	Annual Maintenance Cost (at 5% of Cap. Inv.), $	Annual Taxes and Overhead (at 0.8% of Cap. Inv.), $	Annual Contractor Waste Hauling and Disposal Charge,(f) $	Costs for Handling and Disposal of Wastes: Total Annual Cost, $	Cost, $/metric ton	Cost, ¢/m² Processed(g)
310	2,000	-	155	25	10,570	13,370	43.88	1.74
60	400	-	30	5	290	845	69.55	0.11
40	200	-	20	5	50	355	169.05	0.05
410	2,600	-	205	35	10,910	14,570	45.67	1.89
835	2,000	300	420	65	3,325	7,785	102.10	1.01
60	400	-	30	5	405	960	79.01	0.12
40	200	-	20	5	70	375	178.57	0.05
935	2,600	300	470	75	3,800	9,120	100.7[illegible]	1.18
835	2,000	300	420	65	5,425	9,880	129.5[illegible]	1.28
60	400	-	30	5	660	1,215	100.00	0.16
40	200	-	20	5	110	415	197.62	0.05
935	2,600	300	470	75	6,195	11,510	127.18	1.49
450	3,000	-	225	35	24,345	28,505	40.70	1.52
80	600	-	40	5	605	1,410	55.62	0.07
50	300	-	25	5	85	515	143.06	0.03
100	400	-	50	10	725	1,385	47.29	0.07
680	4,300	-	340	55	25,760	31,815	41.94	1.70
2,130	3,000	520	1,065	170	7,655	10,670	94.72	0.89
80	600	-	40	5	845	1,650	65.09	0.09
50	300	-	25	5	120	500	152.78	0.03
100	400	-	50	10	1,015	1,675	57.19	0.09
2,360	4,300	520	1,180	190	9,635	20,545	87.72	1.10
2,130	3,000	520	1,065	170	12,495	21,510	122.22	1.15
80	600	-	40	5	1,380	2,185	86.19	0.12
50	300	-	25	5	195	625	173.61	0.03
100	400	-	50	10	1,650	2,310	78.87	0.12
2,360	4,300	520	1,180	190	15,720	26,630	113.71	1.42
790	4,000	-	395	65	56,330	62,370	38.48	1.46
120	800	-	60	10	1,405	2,515	42.88	0.06
60	400	-	30	5	100	655	155.95	0.02
100	600	-	50	10	725	1,585	54.11	0.04
1,070	5,800	-	535	90	58,560	67,125	39.19	1.57
5,180	4,000	810	2,590	415	17,715	35,890	88.40	0.81
120	800	-	60	10	1,960	3,070	52.34	0.07
60	400	-	30	5	140	695	165.48	0.02
100	600	-	50	10	1,015	1,875	64.02	0.04
5,460	5,800	810	2,730	440	20,830	41,530	83.38	0.97
5,180	4,000	810	2,590	415	28,905	47,080	115.96	1.19
120	800	-	60	10	3,200	4,310	73.49	0.10
60	400	-	30	5	230	785	186.90	0.02
100	600	-	50	10	1,650	2,510	85.96	0.06
5,460	5,800	810	2,730	440	33,985	54,685	109.79	1.28

(e) A 10-year straight-line depreciation (i.e., 10%/yr) was applied to the investment cost for the waste-dewatering and/or waste storage equipment. An interest charge of 10 percent was applied to the capital investment for equipment.

(f) This represents the total annual fee paid by the electroplater/metal finisher to the contractor for collecting, hauling, handling and landfill disposal of the wastes. The contractor charges for total handling and disposal of wastes in Level I, II, and III Technology landfills are shown in Table 56.

(g) The annual processing rates for the 16-man, 38-man and 87-man plants are 770,000, 1,870,000 and 4,280,000 m²/yr respectively.

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The centrifuge size was calculated on the basis of a total operating time of 8 hours per day. The capacity of the centrifuge required was as follows:

$$\frac{6910}{8(60)} = 14.40 \text{ liters/min } (3.80 \text{ gal/min}) .$$

Allowing for a 40 percent oversize for safety, the rating of the centrifuge unit required is:

$$14.40\ (1.40) = 20.16 \text{ liters/min } (5.33 \text{ gal/min}) .$$

Using Figure 12, the estimated capital cost of the centrifuge unit was $15,000. The total installed cost of the overall centrifuge system, including piping, pump, etc., was arrived at by applying a factor of 1.3 to the basic centrifuge unit cost. The installed cost of the centrifuge system was:

$$\$15{,}000 \times 1.3 = \$19{,}500 .$$

Similar calculations were made for sizing the centrifuge units required for the 16-man and 87-man model plants.

A vacuum filter, or some other type of filter unit could be employed instead of the centrifuge to dewater the sludge to a 20 percent solids content. The equipment costs and operating costs for the filter units would be closely comparable to those for centrifuges.

Contractor Waste Treatment and Disposal Costs

Contractor hauling, treatment, and off-site landfill disposal of electroplating and metal finishing wastes (destined for disposal on land) was employed at the three model plants for the three technology levels. Such contractor treatment and disposal of wastes had been identified as the prevalent practice in the industry. The wastes from all four streams [i.e., water pollution control (WPC) sludge, process wastes, degreaser sludge, and electroless Ni-bath treatment sludge] were considered potentially hazardous and were handled and disposed of in the same manner.

The contractor charges for combined hauling, treatment, and disposal of the wastes, as indicated earlier in this section of the report, were as shown in the tabulation below:

Technology Level	Disposal	Contractor Waste Hauling, Treatment, and Disposal Charge
I	Simple or Municipal Landfill	3.6¢/liter (13.6¢/gal)
II	Approved Landfill	5.0¢/liter (19.0¢/gal)
III	Secured Landfill	8.2¢/liter (31.0¢/gal)

The same charge was applied to wastes from the different streams, since the wastes from all streams were considered potentially hazardous.

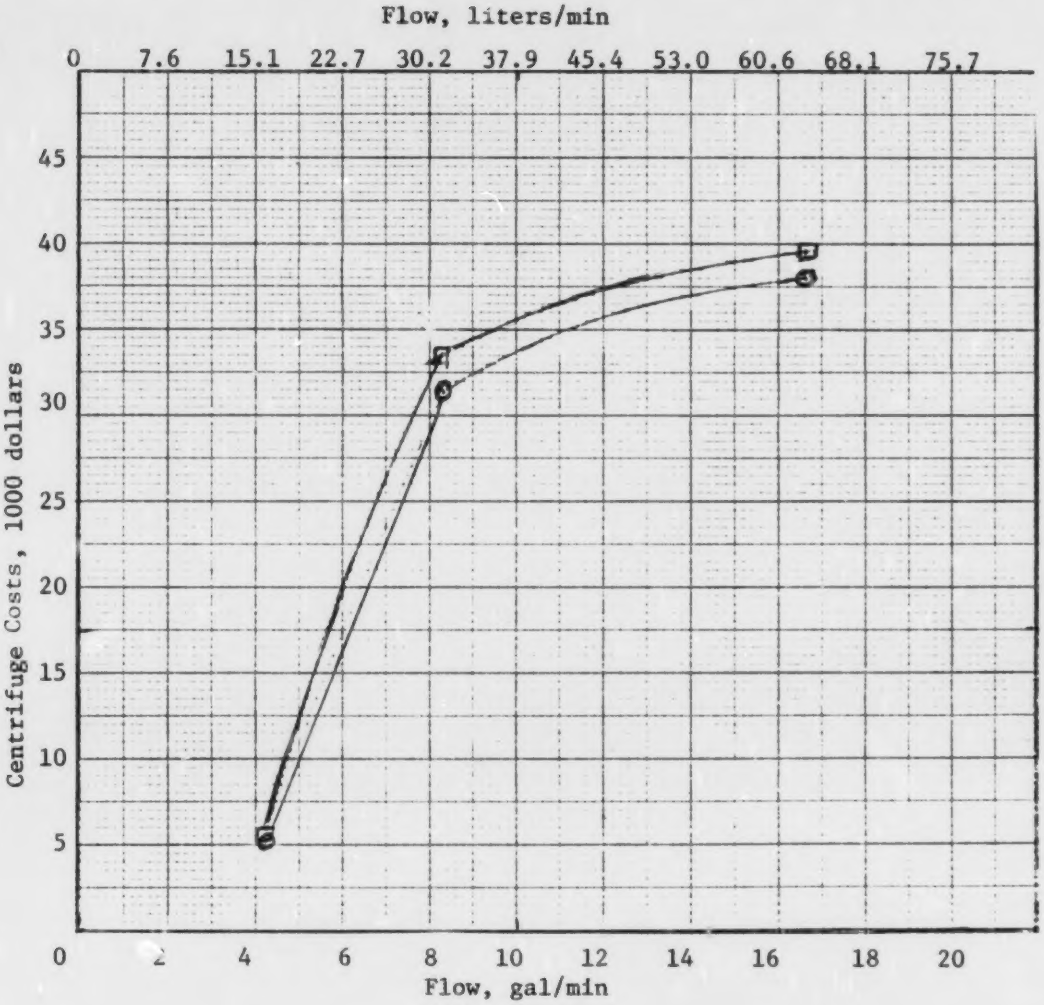

FIGURE 12. CENTRIFUGE CAPACITIES AND COSTS

Upper curve shows adjusted costs to December, 1973, using M&S factor of $\frac{350}{338}$ = 1.04.

References: Zievers, J.F., Finisher's Management, Vol. 18, No. 2, Feb. 1973, pp. 51-54.

M&S Equipment Cost Index, Chemical Engineering, Vol. 82, No. 3, Feb. 3, 1975, p. 120.

Discussion of Model Plant Costs for Handling and Disposal of Wastes

The total annual costs for handling [which includes costs for dewatering of the WPC sludges, storage of the various wastes and sludges at the electroplating plant site, contractor collection, and hauling and chemical treatment (if any) of wastes] and contractor disposal of the model plant wastes in landfills are shown in Column 16 of Table 57 for Technology Levels I, II, and III. The unit cost based on cents per unit area processed (expressed as cents per m^2 processed), as given in Column 20, provides a useful means of comparison of waste handling and disposal costs for the three different sized plants at the three technology levels. Unit costs for handling and disposal of wastes on a volumetric basis, i.e., cents per liter and cents per gallon, are given in Columns 17 and 18, respectively. Unit costs for handling and disposal of waste on a weight basis, i.e., dollars per metric ton, are given in Column 19.

Using the model plant data presented in Table 57, the contractor charges for hauling, treatment, and disposal of wastes were developed for converting from costs/unit volume of waste to costs/weight of waste and costs/area product processed. The contractor charges for combined hauling, treatment, and disposal of electroplating and metal finishing wastes for different technology levels are summarized in the tabulation below:

Technology Level	Disposal	Average Contractor Waste Hauling, Treatment and Disposal Charges			
		¢/liter	¢/gal	$/ metric ton	$/1000 m^2 Processed
I	Simple or Municipal Landfill	3.6	13.6	34.30	13.00
II	Approved Landfill	5.0	19.0	41.95	5.00
III	Secured Landfill	8.2	31.0	68.45	8.15

Summarized estimated costs for treatment and disposal of individual and combined stream wastes at three technology levels for the three different sized electroplating and metal finishing model plants are presented in Table 58. This table permits easy comparison of treatment and disposal costs for particular types of wastes at different technology levels in different sized plants.

Plots of the annual costs versus model plant size and the unit costs per area processes versus plant size for handling and disposing of the wastes at the three treatment technology levels are shown in Figure 13. It is readily apparent from Figure 13 or Tables 57 and 58 that the costs for handling and disposing of the wastes for Level I technology are significantly higher than those for Levels II and III for all the model plants. The reason for this apparent anomaly is the fact that Level I technology involves the handling and disposal of WPC sludges containing 5 percent solids as opposed to WPC sludges containing 20 percent solids for Technology Levels II and III. Dewatering the sludge from 5 to 20 percent solids results in a 4.4-fold reduction in the volume of sludge, and accounts for the significantly lower overall handling and disposal costs for Levels II

TABLE 58. SUMMARIZED ESTIMATED COSTS FOR TREATMENT AND DISPOSAL OF DIFFERENT WASTE STREAMS AT THREE TECHNOLOGY LEVELS FOR THREE DIFFERENT SIZED ELECTROPLATING AND METAL FINISHING MODEL PLANTS(a)

	Costs for Treatment and Disposal of Wastes for Different Sized Model Plants								
	16-Man Plant			38-Man Plant			87-Man Plant		
Waste Stream and Technology Level(b)	Total Annual Cost, $	$/metric ton	¢/m^2 Processed	Total Annual Cost, $	$/metric ton	¢/m^2 Processed	Total Annual Cost, $	$/metric ton	¢/m^2 Processed
WTC Sludge									
Level I	13,370	43.88	1.74	28,505	40.70	1.52	67,370	38.38	1.46
Level II	7,785	102.10	1.01	16,670	94.72	0.89	35,890	88.40	0.84
Level III	9,880	129.57	1.28	21,510	122.22	1.15	47,080	115.96	1.10
Process Wastes									
Level I	845	69.55	0.11	1,410	55.62	0.07	2,515	42.88	0.06
Level II	960	79.01	0.12	1,650	65.09	0.09	3,070	52.34	0.07
Level III	1,215	100.00	0.16	2,185	86.19	0.12	4,370	73.49	0.10
Degreaser Sludge									
Level I	355	169.05	0.05	515	143.06	0.03	655	155.95	0.02
Level II	375	178.57	0.05	550	152.78	0.03	695	165.48	0.02
Level III	415	197.62	0.05	625	173.61	0.03	785	186.90	0.02
Electroless Nickel Sludge									
Level I	-	-	-	1,385	47.29	0.07	1,585	54.11	0.04
Level II	-	-	-	1,675	57.19	0.09	1,875	64.02	0.04
Level III	-	-	-	2,310	78.87	0.12	2,510	85.96	0.06
Combined Streams									
Level I	14,570	45.67	1.89	31,815	41.94	1.70	67,125	39.19	1.57
Level II	9,120	100.77	1.18	20,545	87.72	1.10	41,530	83.38	0.97
Level III	11,510	127.18	1.49	26,630	113.71	1.42	54,685	109.79	1.23

(a) The annual processing rates for the 16-man, 38-man, and 87-man plants are 770,000, 1,870,000, and 4,280,000 m^2/year, respectively.

(b) See Table 57 for description of waste streams and other data related to model plant operations.

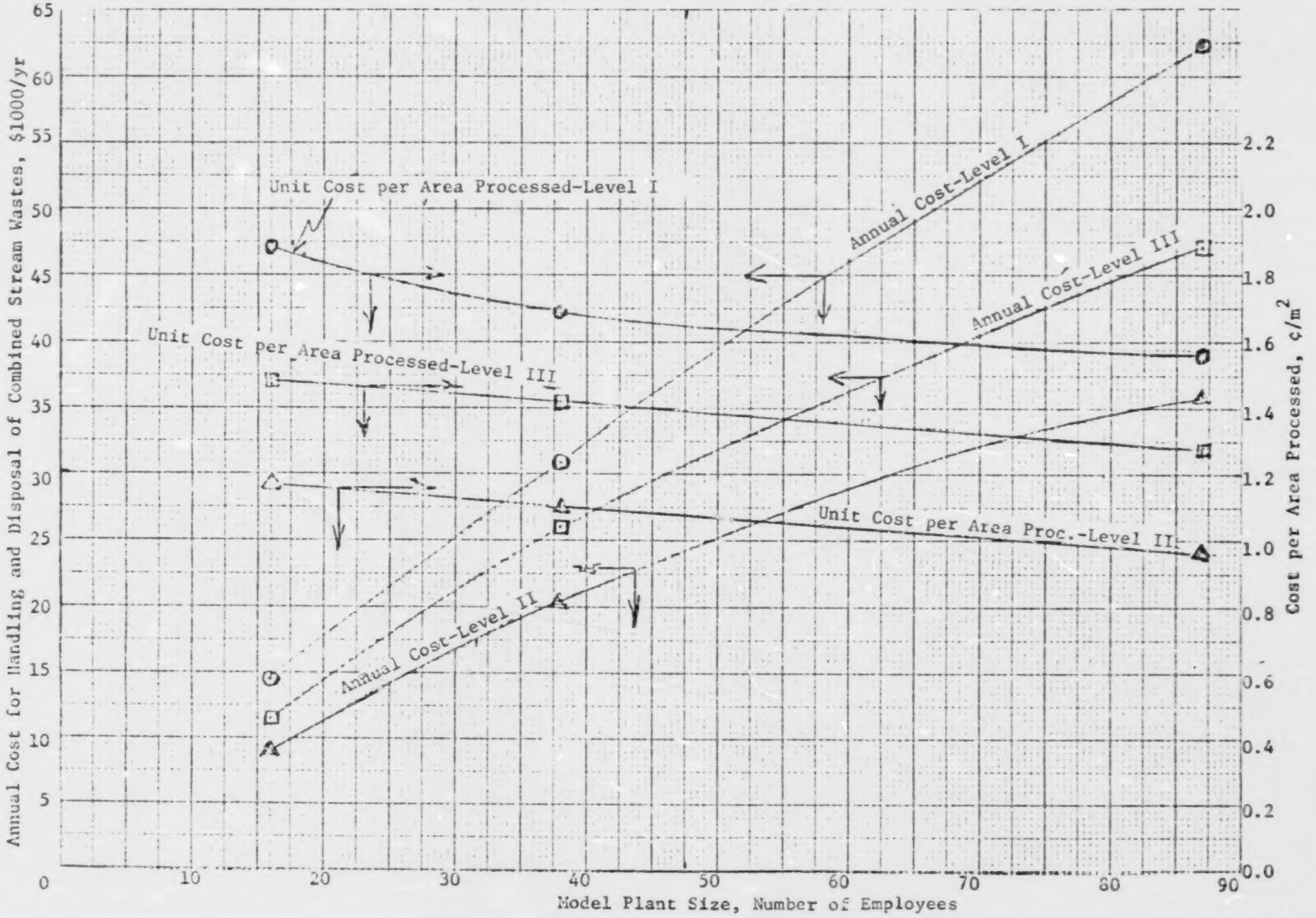

FIGURE 13. WASTE TREATMENT AND DISPOSAL COSTS FOR MODEL PLANTS AT THREE TREATMENT TECHNOLOGY LEVELS

and III. The Level I costs were greater than the Level II and III costs, even though the contractor charges for the combined treatment and disposal of wastes for Level I were 3.6¢ per liter ($34.30/metric ton or $/1000 m^2 processes) as opposed to contractor charges of 5.0¢ per liter ($41.95/metric ton or $/1000 m^2 processed) and 8.2¢ per liter ($68.45/metric ton or $/1000 m^2 processed) for Levels II and III, respectively. As expected, the waste handling and disposal costs for Level II technology were lower than those for Level III technology, with the cost difference being accounted for by the higher contractor charge for disposal in a secured landfill.

The following are generalized comments regarding the costs for treatment and disposal (T&D) of the individual and combined stream wastes for different technology levels for different sized model plants (Tables 43 and 44):

A. WPC Sludge

(1) Costs for treatment and disposition of the WPC sludges constituted more than 80 percent of the total costs for treatment and disposition of combined stream wastes irrespective of treatment technology level or plant size.

(2) For all plant sizes, costs for T&D of WPC sludge were highest for Level I technology, intermediate for Level III, and lowest for Level II. The reasons for this cost-treatment level pattern were discussed in the preceding paragraph of this report.

(3) T&D costs, expressed as $/metric ton, decreased slightly with increased plant size for all technology levels. The lower costs are the result of lower unit costs in the larger plants for handling, dewatering (Levels II and III), and storage of the WPC sludges prior to their being hauled away for treatment and disposal by a contractor.

B. Process Wastes

(1) T&D costs for process wastes increased with treatment technology level primarily because of the higher costs associated with the disposition of wastes in a secured landfill (Level III) as opposed to disposition in an approved landfill (Level II-intermediate cost), or in a simple or municipal landfill (Level I-lowest cost). The bulk density of the process wastes is the same for the three technology levels.

(2) T&D costs for process wastes decreased slightly with increased plant size at all technology levels. The lower costs are attributed to the lower unit costs in the larger plants for handling and storage of the process wastes prior to their being hauled away for treatment and disposal by a contractor.

(3) T&D costs for process wastes, irrespective of treatment technology level or plant size, constituted 11 percent or less of the total costs for treatment and disposition of the combined waste streams for a plant.

C. Degreaser Sludge

(1) T&D costs for degreaser sludge wastes increased with treatment technology level mainly because of the higher costs associated with disposition of the wastes in a secured landfill (Level III) as opposed to disposition in an approved (Level II) landfill or in a simple or municipal (Level I) landfill.

(2) T&D costs for degreaser sludge wastes, irrespective of plant size or technology level, were relatively small and amounted to about 4 percent or less of the total costs for treatment and disposition of the combined stream wastes.

D. Electroless Nickel Sludge

(1) T&D costs for electroless nickel sludge increased with treatment technology level primarily because of the higher costs associated with disposition of the sludge in the higher level landfills.

(2) T&D costs for the electroless nickel sludge, irrespective of treatment technology level or plant size, amounted to less than 9 percent of the total costs for treatment of the combined stream wastes from any of the plants.

E. Combined Streams

(1) For all plant sizes, costs for T&D of the wastes from the combined streams were highest for Level I technology, intermediate for Level III, and lowest for Level II. T&D costs for the WPC sludge stream account for 80 percent or more of the costs for treatment and disposition of the combined stream wastes in any of the plants, so that comments made above under (A) for WPC sludge costs also generally apply to the costs for the combined stream wastes.

As indicated above, because of the significantly larger volumes of waste generated in the water pollution control (WPC) stream in comparison to the other waste streams, the costs for handling and disposing of the WPC sludge ranged from about 80 to 93 percent of the costs for the combined waste streams irrespective of treatment technology level. Accordingly, the use of in-process controls, such as save rinses, or the use of techniques such as evaporation, reverse osmosis, or ion exchange for the recovery of dragout chemicals, offers the most promise for reducing the quantity of sludge and thereby cutting the costs related to the treatment and disposal of the WPC sludges at all treatment levels.

National Costs for Treatment and Disposal of Electroplating and Metal Finishing Wastes for 1975

The projected quantities of the various wastes (destined for land disposal) to be generated nationally in the different plant size categories for 1975 are presented in Table 59. The quantity of waste in the 16-man plant category includes those facilities having 4 to 25 employees; the 38-man plant is representative of plants having 26 to 50 employees; and the 87-man plant covers plants with more than 50 employees.

The annual cost data for the treatment and disposal of the various waste streams in the model plants for the three technology levels, as presented in Table 43, were used in conjunction with the waste stream load data to determine the unit costs for the treatment and disposal of wastes in each plant-size category, as shown in Table 44, Columns 4, 5, and 6. Multiplying the unit-cost (expressed in \$/metric ton of waste as indicated in Footnote (d) of Table 59) values in Column 6 by the projected quantity of waste shown in Column 3 gives the national cost for the treatment and disposal of that particular waste in all U. S. plants in that size category for a particular technology level.

The total costs for the treatment and disposal, at the three technology levels, of WPC sludges, process wastes, degreaser sludges, and electroless nickel sludges for all U. S. job shops for 1975 are shown on an individual-stream and combined-stream basis at the bottom right of Table 59. The costs were highest for the Level I technology, intermediate for Level III technology, and lowest for Level II technology. The reasons for this cost-technology level pattern are the same as those that had been presented and discussed in the previous subsection of the report entitled "Discussion of Model Plant Costs for Handling and Disposal of Wastes".

In the "Economics Characteristics" subsection in the "Industry Characterization" section of this report, it was indicated that the value added in the electroplating and metal finishing industry (job shops) was \$749,100,000 for 1972.* Assuming an inflation value of six percent to convert the 1972 value to December, 1973, dollars, the value-added figure becomes \$794,000,000. The ratios of waste treatment and disposal costs at the different technology levels to the value-added statistic for the industry range from 1.83 to 2.60 percent for 1975 (Table 60).** The significantly lower ratio value of 1.83 percent for Level II technology as opposed to 2.60 percent for Level I technology results from the fact that the amount of WPC sludge hauled away for disposal in Level II technology is markedly less than for Level I technology. This is primarily because the WPC sludge is dewatered to a solids content of 20 percent in Level II technology as opposed to a solids content of 5 percent for Level I technology, which significantly lowers handling and disposal costs for Level II technology. The ratio value for Level III technology is 2.26 percent, which is intermediate between the ratio for Level I and Level III technologies. Although Level III technology employs dewatering the WPC sludge to the same solids content as Level II technology, the higher costs of overall treatment and

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* "Economic Analysis of Effluent Guidelines - The Metal Finishing Industry", EPA 230/1-74-032, September, 1974, page VI-8.

** For this calculation, it was assumed that the production data for 1975 were similar to those for 1972 for which value-added data were available.

TABLE 59. 1975 NATIONAL COSTS FOR THE TREATMENT AND DISPOSAL OF ELECTROPLATING AND METAL FINISHING WASTES AT DIFFERENT TECHNOLOGY LEVELS[a]

Waste Stream[b]	Plant Size Category[c]	Annual Quantity of Waste Projected Nationally for 1975 by Weight,[d] metric tons/yr	Annual Model Plant Treatment and Disposal Data[e]				National Costs at Different Technology Levels for Different Size Category Plants		
			Quantity,[d] kg/yr	Total Cost, $/yr	Unit Cost,[d] $/metric ton	Unit Cost, $/1000 m^2 Processed	I $1000/yr	II $1000/yr	III $1000/yr
WPC Sludge[b]									
Level I	16-man	6,453	15,200	13,370	880	1,740	5,679		
Level II	"	6,453	15,200	7,785	512	1,010		3,304	
Level III	"	6,453	15,200	9,880	650	1,280			4,194
Process Wastes									
Level I	16-man	14,690	12,110	845	69.7	110	1,024		
Level II	"	14,690	12,110	960	79.3	120		1,165	
Level III	"	14,690	12,110	1,215	100.4	160			1,475
Degreaser Sludge									
Level I	16-man	2,486	2,050	355	173	50	430		
Level II	"	2,486	2,050	375	183	50		455	
Level III	"	2,486	2,050	415	202	50			502
Combined Streams	16-man	--	--	--	--	--	7,133	4,924	6,171
WPC Sludge									
Level I	38-man	6,762	35,000	28,505	814	1,520	5,504		
Level II	"	6,762	35,000	16,670	476	890		3,219	
Level III	"	6,762	35,000	21,510	615	1,150			4,159
Process Wastes									
Level I	38-man	13,971	25,310	1,410	55.7	70	778		
Level II	"	13,971	25,310	1,650	65.2	90		911	
Level III	"	13,971	25,310	2,185	86.3	120			984
Degreaser Sludge									
Level I	38-man	1,982	3,590	515	143	30	283		
Level II	"	1,982	3,590	550	153	30		303	
Level III	"	1,982	3,590	625	174	30			345

TABLE 59. (Continued)

Waste Stream(b)	Plant Size Category(c)	Annual Quantity of Waste Projected Nationally for 1975 by Weight,(d) metric tons/yr	Annual Model Plant Treatment and Disposal Data(e) Quantity,(d) kg/yr	Total Cost, $/yr	Unit Cost,(d) $/metric ton	Unit Cost, $/1000 m^2 Processed	National Costs at Different Technology Levels for Different Size Category Plants I $1000/yr	II $1000/yr	III $1000/yr
Electroless-Ni Sludge									
Level I	38-man	8,073	14,625	1,385	94.7	70	765		
Level II	"	8,073	14,625	1,675	115	90		928	
Level III	"	8,073	14,625	2,310	158	120			1,276
Combined Wastes	38-man	--	--	--	--	--	7,330	5,361	6,764
WPC Sludge									
Level I	87-man	6,577	81,000	62,370	770	1,460	5,064		
Level II	"	6,577	81,000	35,890	443	840		2,914	
Level III	"	6,577	81,000	47,080	581	1,110			3,281
Process Wastes									
Level I	87-man	13,590	58,580	2,515	42.9	60	583		
Level II	"	13,590	58,580	3,070	52.4	70		712	
Level III	"	13,590	58,580	4,310	73.6	100			1,000
Degreaser Sludge									
Level I	87-man	977	4,210	655	156	20	152		
Level II	"	977	4,210	695	165	20		161	
Level III	"	977	4,210	785	186	20			182
Electroless-Ni Sludge									
Level I	87-man	3,393	14,625	1,585	108	40	366		
Level II	"	3,393	14,625	1,875	128	40		434	
Level III	"	3,393	14,625	2,510	172	60			584
Combined Wastes	87-man	--	--	--	--	--	6,165	4,221	5,047

TABLE 59. (Continued)

Waste Stream[(b)]	Plant Size Category[(c)]	Annual Quantity of Waste Projected Nationally for 1975 by Weight,[(d)] metric tons/yr	Annual Model Plant Treatment and Disposal Data[(e)]				National Costs at Different Technology Levels for Different Size Category Plants		
			Quantity,[(d)] kg/yr	Total Cost, $/yr	Unit Cost,[(d)] $/metric ton	Unit Cost, $/1000 m^2 Processed	I $1000/yr	II $1000/yr	III $1000/yr
			Total U.S. Costs (Combined Plant Categories)						
WPC Sludge	All U. S. Plants	19,792	--	--	--	--	16,247	9,437	11,634
Process Wastes	"	42,251	--	--	--	--	2,385	2,788	3,459
Degreaser Sludge	"	5,445	--	--	--	--	865	919	1,029
Electroless-Ni Sludge	"	11,466	--	--	--	--	1,131	1,362	1,860
Combined Streams	"	78,954	--	--	--	--	20,628	14,506	17,982

(a) All costs are expressed in terms of December, 1973, dollars.

(b) The quantity of water pollution control (WPC) sludges generated in 1975 was taken as equivalent to 35 percent of the WPC wastes to be generated in 1977 for each plant size category. The quantity of process water, solvent sludges, and electroless-Ni sludges for 1975 was the same as that projected for 1977.

(c) The 16-man plant category was considered representative of plants having 4 to 25 employees; the 38-man plant was representative of plants having 26-50 employees; plants with more than 50 employees were considered to be represented by the 87-man plant.

(d) The weights shown for the WPC sludge, process wastes, and electroless-Ni sludge are on a dry-weight basis. The weights of the degreaser sludge are expressed on an as-is basis.

(e) See Table 71 for model plant data.

TABLE 60. COMPARISON OF WASTE TREATMENT AND DISPOSAL COSTS TO VALUE ADDED STATISTIC FOR THE ELECTROPLATING AND METAL FINISHING INDUSTRY FOR DIFFERENT TREATMENT TECHNOLOGY LEVELS(a)

Year	Annual Value Added Statistic, dollars	National Waste Treatment and Disposal Cost, dollars/year	Treatment Technology Level Level	Ratio of Waste Treatment and Disposal Costs to Value Added Statistic Expressed as a Precentage Value, percent
1975(a)	794,000,000	20,628,000	I	2.60
	794,000,000	14,506,000	II	1.83
	794,000,000	17,982,000	III	2.26

(a) Costs are expressed in terms of constant December, 1973, dollars.

disposal for Level III technology over Level II technology arise from the higher cost of using a secured landfill for Level III as opposed to a less costly approved landfill for Level II. The above ratios of waste treatment and disposal cost to value added show that the waste treatment and disposal cost constitutes an important segment of the overall production costs in the electroplating and metal finishing industry.

APPENDIX A

METHODOLOGY FOR ACQUIRING INFORMATION

APPENDIX A

METHODOLOGY FOR ACQUIRING INFORMATION

For many years Battelle has worked with the electroplating and metal finishing industries in the development and improvement of electroplating techniques and in the assessment of environmental control technology Much of the information acquired during those past studies was available for the current investigation of hazardous waste management practices.(aa,bb,cc) As a preliminary step in the acquisition and analysis of the data, this initial data base was reviewed and the pertinent information from it has been included.

However, from the beginning of the study, the need for much more detailed data was recognized and steps were taken to procure these data. The first such step was to seek the cooperation and involvement of the appropriate industrial organizations. Both the U.S. Environmental Protection Agency and Battelle had approached these organizations prior to the beginning of the study and were assured of their intent to cooperate.

Industry Survey

Following the award of the contract, a meeting was held on August 1, 1974, with the following trade associations to develop a method for interaction and data acquisition: the National Association of Metal Finishers (NAMF), the American Electroplater's Society (AES), the Metal Finishers Suppliers' Association (MFSR), and the Institute of Printed Circuits (IPC). One of the objectives of that meeting was to review a draft data-acquisition form which had been developed by Battelle for the survey of the industry. During the meeting it was agreed that the data-acquisition form should be revised and field tested before it was mailed. It also was agreed that the NAMF would mail out the data-acquisition form to provide the broadest possible coverage of the entire electroplating and metal finishing industries.

The mechanism of the industry survey consisted of mailing about 7,000 of the data-acquisition forms shown in Figure A-1 by NAMF through the Association's headquarters office; the return of the completed questionnaire to that office; the removal of identifying information; the attachment of a code number; and the forwarding of anonymous information to BCL. The mailing list used was known only to the NAMF office.

Battelle received 131 forms, 24 of which were marked "no plating done". Of the remaining 107 forms, 79 were from job shops, 26 were from captive shops, and two were from shops which classified themselves as both. Of the 107 forms, 38 reported no wastes or gave no entry on the form. Of the 69 forms containing entries dealing with wastes, the entries varied in detail from only the name and the source of the waste to detailed presentations of quantities and analyses. Most respondents gave some information

SOLID WASTE DISPOSAL QUESTIONNAIRE

Company Name ______________________________

Address ______________________________

Telephone No. ______________________________

Code No. ______________________________
(Code Number to be filled in by NAMF)

This page will be kept by the NAMF, and will not be given to the Environmental Protection Agency or the contractor working for the EPA.

The following questions are directed at obtaining information on

(1) Wastes from electroplating or metal-finishing operations.
(2) Wastes destined for disposal on land (for example, sludges) not including ordinary paper and trash.

This questionnaire is being sent to both job shops and captive shops. Only those wastes from cleaning, electroplating, acid treatments, and similar processes are considered here. Wastes from painting, lacquering, or other ogranic coating processes are not included.

Disposal Contractors Used

Name ____________ ____________ ____________

Address ____________ ____________ ____________

Service ____________ ____________ ____________

Type of Waste ____________ ____________ ____________

FIGURE A-1. NAMF QUESTIONNAIRE

(NOTE: THIS FORM TO BE RETAINED BY NAMF OFFICES)

CONFIDENTIAL -- THIS IS TRADE SECRET INFORMATION - CONFIDENTIAL

Questionnaire Code Number ____________ (by NAMF)

Geographical Location ____________________

State ____________________

Plant Operations and Characteristics

Type of Plant: Job Shop ____________ ___Captive ____________

Your Standard Industrial Classification (if known) SIC No. ____________

Number of Employees: Total Plant ________ Metal Finishing Production ________

Production Characteristics

Type of Process: (Please check as many as apply)

Electroplating ______	Phosphating ______	Hot Dipping ______
Anodizing ______	Bright Dipping ______	Deburring ______
Electroless Plating ____	Chemical Polishing ______	Passivating ______
Chromating ______	Dying ______	Lead Stripping ______

Metals Deposited ________________________________

Metals and Materials Purchased Monthly for Metal Finishing and Electroplating (please list in pounds/month or gallons/month)

Metal Anodes	Metal Salts or Oxides
Copper ____________	____________
Zinc ____________	____________
Chromium ____________	____________
Nickel ____________	____________
Tin ____________	____________
Cadmium ____________	Acids, Solvents, Alkaline Cleaners ______
Lead ____________	____________
Other ____________	____________
____________	____________
____________	____________

Total Volume of Sales of Plating Facility, dollars per month ____________

Power Consumed Monthly for Metal Finishing ____________

Installed Rectifier Capacity ____________ Average Operating Level, % of Rated ________

Estimated Square Feet Plated Monthly ____________

Plant Operating Rate ________ Hrs/day ____________ days/week

Age of Plating Plant Equipment (Range or Average) ____________

Metal Finishing Production ____________

Metal Finishing Waste Treatment ____________

Types of Other Operations on Plant Site ____________

____

Please give information on all industrial wastes from your electroplating plant DESTINED FOR DISPOSAL ON LAND, but not including paper and general trash. This will most likely include information on sludges from water treatment, sludges from sumps, waste or spent chemicals, spent solvents, used abrasives, filter aides, baghouse dusts, or other wastes which would be disposed of in a landfill or dump.

	Type of Waste (sludge, dust, spent chemicals, or other)	Source (water pollution control, air pollution control, finishing, plating, or other)	Quantity* (gallons/day – pounds/month)
1.			
2.			
3.			
4.			

* If a sludge, please indicate wet or dry basis, or, if wet, percent solids.

Please indicate any planned or estimated changes in wastes from electroplating or metal finishing destined for land disposal in the future.
Will there be new or increased amounts of sludges from water treatment because of water pollution control regulations? (Scheduled for 1977 and 1983)

Yes__________ No__________

If possible, please give estimates of industrial wastes destined for land disposal in 1977 and 1983.

Estimated Future Wastes in 1977

	Type of Waste	Source	Quantity (Please indicate amount if possible, or more or less, or same)
1.			
2.			
3.			
4.			

Please indicate if possible, the reason for any change in amount of sludges or other wastes to be disposed of (for example, water pollution control, increased production, process changes, or recycle of waste)____________________

Estimated Future Wastes in 1983

Type of Waste	Source	General Estimate Quantity (More, less, same)
1.		
2.		
3.		
4.		

If changes in quantities of wastes from electroplating or metal finishing destined for land disposal are expected, what is the reason for the change? For example: increased production, installation of water pollution control equipment, installation of sludge drying equipment, etc.

Characteristics of all Industrial Wastes from Electroplating and Metal Finishing Destined for Land Disposal (except miscellaneous trash). Please use following sheets and indicate what is known, concentrations, present, absent, not analyzed, or estimated ranges (each column is for a different waste).

Characteristics of Wastes (Present)

Type of Waste				
Source of Waste*				
Units of Concentration (wt %, mg/1, ppm)				
Asbestos				
Arsenic				
Beryllium				
Cadmium				
Calcium				
Chromium (+6)				
Chromium (total)				
Copper				
Cyanide				
Iron				
Lead				
Magnesium				
Mercury				
Nickel				
Selenium				
Zinc				
Other Metals				
Solvents				
Cleaners				
Phosphates				
Sulfates				
Oils & Greases				
Soaps				
Water Content				

*Examples of Sources of Waste would be waste-water treatment plant, sludge drier, some particular sump, etc.

Characteristics of Wastes (1977)

Please indicate characteristics of wastes from electroplating and metal finishing destined for disposal on land expected in 1977 (each column is for a separate waste). If concentrations cannot be predicted, indicate as present, absent, major, minor etc.

Type of waste				
Source of Waste*				
Units of Concentration (wt %, mg/1, ppm)				
Asbestos				
Arsenic				
Beryllium				
Cadmium				
Calcium				
Chromium (+6)				
Chromium (total)				
Copper				
Cyanide				
Iron				
Lead				
Magnesium				
Mercury				
Nickel				
Selenium				
Zinc				
Other Metals				
Solvents				
Cleaners				
Phosphates				
Sulphates				
Oils & Grease				
Soaps				
Water Content				

* Examples of Sources of Waste would be waste-water treatment plant, sludge drier, some particular sump, etc.

Characteristics of Wastes (1983)

Type of Waste	________	________	________	________
Source of Waste *	________	________	________	________
Units of Concentration (wt %, mg/1, ppm)	________	________	________	________
Asbestos	________	________	________	________
Arsenic	________	________	________	________
Beryllium	________	________	________	________
Cadmium	________	________	________	________
Calcium	________	________	________	________
Chromium (+6)	________	________	________	________
Chromium (total)	________	________	________	________
Copper	________	________	________	________
Cyanide	________	________	________	________
Iron	________	________	________	________
Lead	________	________	________	________
Magnesium	________	________	________	________
Mercury	________	________	________	________
Nickel	________	________	________	________
Selenium	________	________	________	________
Zinc	________	________	________	________
Other Metals				
________	________	________	________	________
________	________	________	________	________
________	________	________	________	________
Solvents				
________	________	________	________	________
________	________	________	________	________
Cleaners				
Phosphates	________	________	________	________
Sulfates	________	________	________	________
Oils & Grease	________	________	________	________
Soaps	________	________	________	________
Water Content	________	________	________	________

* Examples of Sources of Waste would be waste-water treatment plant, sludge drier, some particular sump, etc.

Please check all blanks applicable to Wastes from Electroplating or Metal Finishing

Waste Treatments Now Used Before Disposal
on Land or to Avoid Dumping

Sludge

Dewater ______
  Filter ______
  Incineration ______
Encapsulate ______
Fixed in Cement ______
Recovery and Reuse ______
Other (specify) ______
______

Waste Dusts

Incineration ______
Open Burning ______
Bag or Package ______
Other (Specify) ______
______
Waste Ashes (from incineration)
Package (Bag or Drum) ______
Other (specify) ______
______

Liquids

Organic ______
  Reclaim ______
  To Reclaimer ______
  To Wastewater Treatment ______
  Incineration ______
Inorganic ______
  To Reclaimer ______
  To Wastewater Treatment ______
Recovery and Reuse ______

Method of Disposal (please check all blanks applicable)

Type of Waste				
Source of Waste				
On-Site Disposal				
Off Site Disposal				
Company owned Off-Site				
Sewer				
Lagoon				
Open Dump				
Mine Disposal				
Covered Land Fill				
Hauled by your truck				
Hauled by contractor				
Incinerator				
Deep Well Injection				
Recovery and Reuse				
Sale				
Municipal Dump				
Other (specify)				

COSTS

Please provide information on costs associated with the treatment or disposal of solid or other wastes DESTINED FOR LAND DISPOSAL. The information sought would probably include such things as sludge driers, incinerators, private sludge lagoons, etc. Costs of water pollution control equipment are NOT being sought.

Cost for Contractor Disposal Service (including sludge removal costs but not paper or general trash)

Cost Basis (cents per gallon, dollars per ton, etc.) ______________________

Monthly Costs, dollars per month ______________________

Costs for Waste Treatment Equipment (for example, sludge driers, lagoons, etc.)

Type of Equipment ______________________

Type of Waste Treated ______________________

(a) Capital Investment Costs * Year Costs Incurred ____________

Design Costs .... ______________________

Purchase of land and materials .... ______________________

Site preparation .... ______________________

Construction and installation (includes equipment) .. ______________________

Start-up Costs .... ______________________

Losses due to downtime (production halts during installation) ____________

Total Capital Costs .... ______________________

Debt/Equity Ratio** .... ______________________

Purchase or Truck(s).......................... ______________________

(b) Operating Costs Year of cost figures* ____________

Cost of Capital*** .... ______________________

Interest rate applied ____________

Maintenance

Labor .... ______________________

Materials .... ______________________

Chemicals .... ______________________

Replacement parts .... ______________________

Testing and Analysis.......................... ______________________

Insurances .... ______________________

Taxes .... ______________________

Administrative Costs .... ______________________

Energy and Power Costs .... ______________________

Truck Fuel Costs .... ______________________

Total Operating Costs .... ______________________

(c) Savings

Productivity increases (credit) ____________________

Revenues on by-products or recycle savings ____________________

(d) Net Operating Costs . . . . ____________________

(e) Estimated equipment life expectancy__________

Depreciation Scheme Used__________

Length of time for depreciation__________years

(f) Total solid-waste treatment and disposal costs as percentage of total costs of the electroplating and metals-finishing costs ____________________%

* 1973 cost figures are preferred or indicate year of investment.

** Debt – amount of money borrowed/equity=total amount of money invested.

*** Financial charges which are computed as the cost of capital times the capital expenditures. The cost of capital should be based upon a weighted average of the separate costs of debt and equity.

Would you be willing to receive a plant
visit by the contractor personnel

Yes _____ No _____

If "Yes" please supply:

Company Name ____________________

Address ____________________

____

Telephone Number ____________________

Person To Be Contacted ____________________ on the number of employees, etc., relative to the industry characterization. However, in many cases the responses were not sufficiently consistent to allow correlation of the activities or rationalization of units.

Survey of Private Contractors and Service Organizations

Identification of Contractors, Services, Costs, and Disposal Methods

The identification of waste treatment and disposal contractors and service organizations, the services provided, the service costs, and the treatment and disposal methods employed often required direct contact with these organizations, in addition to analysis of the industry data and data from the report "An Inventory of Hazardous Management Facilities" (IHWMF). To obtain more complete contractor information, a telephone survey was conducted. The survey questions were patterned after the facilities' résumé found in the IHWMF report plus questions regarding the acceptability of a plant visit by program personnel. Plants included in the IHWMF report which were contacted were asked to verify the accuracy and update the data previously provided. A copy of the data-acquisition forms used during the telephone survey is included in this report as Figure A-2. Time made it necessary to limit the total number of contacts to those facilities likely to provide the most relevant information. This was accomplished by applying a screening or selection criterion to potential contacts.

Early in the program, before responses to the NAMF data acquisition forms came in, the only source of information was the IHWMF report. The 65 facilities covered in this report received the bulk of the initial investigative effort. All treatment and disposal contractors listed in the IHWMF report which met the following criteria were contacted by telephone (or contact was attempted):

- The plant site had not been previously visited by another HWMD contractor.
- Wastes accepted fell into the range of waste materials typically produced in electroplating and metal finishing operations (e.g., heavy metals in solution or in sludges, cyanide wastes, acids, caustics, solvents, chlorinated hydrocarbon degreasers, and alkaline cleaners.)

As the project progressed, the names of an additional 42 treatment and disposal contractors from the indistry response (NAMF data acquisition form) became available. All contractors handling potentially hazardous wastes who were identified before January 13, 1975, were contacted (or contact was attempted); later, a one-page follow-up form (See Figure A-3) was sent to 23 NAMF contacts to obtain additional information.

Solid Waste Disposal Questionnaire

Company Name ______________________________

Address ______________________________

Telephone No. ______________________________

The following questions are directed at obtaining information on

(1) Wastes from electroplating or metal-finishing operations

(2) Wastes destined for disposal on land (for example, sludges) not including ordinary paper and trash.

This questionnaire is being sent to both job shops and captive shops. Only those wastes from cleaning, electroplating, acid treatments, and similar processes are considered here.

Wastes from painting, lacquering, or other organic coating processes are not included.

FIGURE A-2. DATA ACQUISITION FORM USED IN BCL TELEPHONE SURVEY

Would you be willing to receive a plant visit by the contractor personnel

Yes ________ No ________

If "Yes" please supply:

Company Name ______________________________

Address ______________________________

____

Telephone Number ______________________________

Person To Be Contacted ____________________

Geographical Location____________________

State____________________

Plant Operations and Characteristics

Type of Plant: Job Shop____________________ Captive____________________

Your Standard Industrial Classification (if known) SIC No.____________________

Number of Employees: Total Plant______ Metal Finishing Production__________

Production Characteristics

Type of Process: (Please check as many as apply)

Electroplating__________

Anodizing__________

Electroless Plating__________

Chromating__________

Phosphating__________

Bright Dipping__________

Chemical Polishing__________

Dying__________

Hot Dipping__________

Deburring__________

Passivating__________

Lead Stripping__________

Metals Deposited____________________

Metals and Materials Purchased Monthly for Metal Finishing and Electroplating (please list in pounds/month or gallons/month)

Metal Anodes

Copper____________________

Zinc____________________

Chromium____________________

Nickel____________________

Tin____________________

Cadmium____________________

Lead____________________

Other____________________

____

____

Metal Salts or Oxides

____

____

____

____

____

Acids, Solvents, Alkaline Cleaners______

____

____

____

____

Total Volume of Sales of Plating Facility, dollars per month____________________

Power Consumed Monthly for Metal Finishing____________________

Installed Rectifier Capacity__________ Average Operating Level, % of Rated______

Estimated Square Feet Plated Monthly____________________

Plant Operating Rate____________hrs/day____________days/week

Age of Plating Plant Equipment (Range or Average)____________________

Metal Finishing Production____________________

Metal Finishing Waste Treatment____________________

Types of Other Operations on Plant Site____________________

____

Please give information on all industrial wastes from your electroplating plant DESTINED FOR DISPOSAL ON LAND, but not including paper and general trash. This will most likely include information on sludges from water treatment, sludges from sumps, waste or spent chemicals, spend solvents, used abrasives, filter aides, baghouse dusts, or other wastes which would be disposed of in a landfill or dump.

Type of Waste (sludge, dust, spent chemicals, or other)	Source (water pollution control, air pollution control, finishing, plating, or other)	Quantity* (gallons/day - pounds/month)
1.		
2.		
3.		
4.		

* If a sludge, please indicate wet or dry basis, or, if wet, percent solids.

Please indicate any planned or estimated changes in wastes from electroplat
or metal finishing destined for land disposal in the future.

Will there be new or increased amounts of sludges from water treatment because of water pollution control regulations? (Scheduled for 1977 and 1983) Yes______________ No______________

If possible, please give estimates of industrial wastes destined for land disposal in 1977 and 1983.

Estimated Future Wastes in 1977

Type of Waste	Source	Quantity (Please indi amount if possible, c more or less, or same
1.______________	______________	______________
2.______________	______________	______________
3.______________	______________	______________
4.______________	______________	______________

Please indicate if possible, the reason for any change in amount of sludges or other wastes to be disposed of (for example, water pollution control, increased production, process changes, or recycle of waste)______________

____

____

____

____

Estimated Future Wastes in 1983

Type of Waste	Source	General Estimate Quantity (More, Less, Same)
1.		
2.		
3.		
4.		

If changes in quantities of wastes from electroplating or metal finishing destined for land disposal are expected, what is the reason for the change? For example: increased production, installation of water pollution control equipment, installation of sludge drying equipment, etc.

Characteristics of all Industrial Wastes from Electroplating and Metal Finishing Destined for Land Disposal (except miscellaneous trash). Please use following sheets and indicate what is known, concentrations, present, absent, not analyzed, or estimated ranges (each column is for a different waste).

Characteristics of Wastes (Present)

Type of Waste ________ ________ ________ ________
Source of Waste* ________ ________ ________ ________
Units of Concentration (wt %, mg/l, ppm) ________ ________ ________ ________

Asbestos ________ ________ ________ ________
Arsenic ________ ________ ________ ________
Beryllium ________ ________ ________ ________
Cadmium ________ ________ ________ ________
Calcium ________ ________ ________ ________
Chromium (+6) ________ ________ ________ ________
Chromium (total) ________ ________ ________ ________
Copper ________ ________ ________ ________
Cyanide ________ ________ ________ ________
Iron ________ ________ ________ ________
Lead ________ ________ ________ ________
Magnesium ________ ________ ________ ________
Mercury ________ ________ ________ ________
Nickel ________ ________ ________ ________
Selenium ________ ________ ________ ________
Zinc ________ ________ ________ ________
Other Metals
________ ________ ________ ________ ________
________ ________ ________ ________ ________
________ ________ ________ ________ ________

Solvents
________ ________ ________ ________ ________
________ ________ ________ ________ ________

Cleaners
Phosphates ________ ________ ________ ________
Sulfates ________ ________ ________ ________
Oils & Grease ________ ________ ________ ________
Soaps ________ ________ ________ ________
Water Content ________ ________ ________ ________

* Examples of Sources of Waste would be wastewater treatment plant, sludge drier, some particular sump, etc.

Characteristics of Wastes (1977)

Please indicate characteristics of wastes from electroplating and metal finishing destined for disposal on land expected in 1977 (each column is for a separate waste). If concentrations cannot be predicted, indicate as present, absent, major, minor, etc.

Type of Waste				
Source of Waste*				
Units of Concentration (wt %, mg/l, ppm)				
Asbestos				
Arsenic				
Beryllium				
Cadmium				
Calcium				
Chromium (+6)				
Chromium (total)				
Copper				
Cyanide				
Iron				
Lead				
Magnesium				
Mercury				
Nickel				
Selenium				
Zinc				
Other Metals				
Solvents				
Cleaners				
Phosphates				
Sulfates				
Oils & Grease				
Soaps				
Water Content				

* Examples of Sources of Waste would be waste-water treatment plant, sludge drier, some particular sump, etc.

Characteristics of Wastes (1983)

Type of Waste				
Source of Waste*				
Units of Concentration (wt %, mg/l, ppm)				
Asbestos				
Arsenic				
Beryllium				
Cadmium				
Calcium				
Chromium (+6)				
Chromium (total)				
Copper				
Cyanide				
Iron				
Lead				
Magnesium				
Mercury				
Nickel				
Selenium				
Zinc				
Other Metals				
________				
________				
________				
Solvents				
________				
________				
Cleaners				
Phosphates				
Sulfates				
Oils & Grease				
Soaps				
Water Content				

* Examples of Sources of Waste would be waste-water treatment plant, sludge drier, some particular sump, etc.

Please check all blanks applicable to Wastes from Electroplating or Metal Finishing

Waste Treatments Now Used Before Disposal on Land or to Avoid Dumping

Sludge

Dewater______________

Filter______________

Incineration__________

Encapsulate____________

Fixed in Cement_________

Recovery and Reuse______

Other (specify)_________

____

Waste Dusts

Incineration__________

Open Burning__________

Bag or Package_________

Other (Specify)________

____

Waste Ashes (from incineration)

Package (Bag or Drum)____

Other (specify__________

____

Liquids

Organic______________

Reclaim______________

To Reclaimer_________

To Wastewater Treatment__________

Incineration_________

Inorganic____________

To Reclaimer_________

To Wastewater Treatment__________

Recovery and Reuse______________

Method of Disposal (please check all blanks applicable)

Type of Waste				
Source of Waste				
On-Site Disposal				
Off-Site Disposal				
Company owned Off-Site				
Sewer				
Lagoon				
Open Dump				
Mine Disposal				
Covered Land Fill				
Hauled by your truck				
Hauled by contractor*				
Incineration				
Deep Well Injection				
Recovery and Reuse				
Sale				
Municipal Dump				
Other(specify)				

* Please supply information on page 11

Disposal Contractors Used

Name ____________ ____________ ____________

Address ____________ ____________ ____________

Service ____________ ____________ ____________

Type of Waste ____________ ____________ ____________

COSTS

Please provide information on costs associated with the treatment or disposal of solid or other wastes DESTINED FOR LAND DISPOSAL. The information sought would probably include such things as sludge driers, incinerators, private sludge lagoons, etc. Costs of water pollution contol equipment are NOT being sought.

Cost for Contractor Disposal Service (including sludge removal costs but not paper or general trash)

Cost Basis (cents per gallon, dollars per ton, etc.) ____________

Monthly Costs, dollars per month ____________

Costs for Waste Treatment Equipment (for example, sludge driers, lagoons, etc.)

Type of Equipment ____________

Type of Waste Treated ____________

(a) Capital Investment Costs* **Year** Costs incurred ________

Design Costs . . . . ____________

Purchase of land and materials . . . . ____________

Site preparation . . . . ____________

Construction and installation (includes equipment) . ____________

Start-up Costs . . . . ____________

Losses due to downtime (production halts during installation) ____________

Total Capital Costs . . . . ____________

Debt/Equity Ratio ** . . . . ____________

Purchase of Truck(s) . . . . ____________

(b) Operating Costs **Year** of cost figures* ________

Cost of Capital*** . . . . ____________

Interest rate applied ________

Maintenance

Labor . . . . ____________

Materials . . . . ____________

Chemicals . . . . ____________

Replacement parts . . . . ____________

Testing and Analysis . . . . ____________

Insurances . . . . ____________

Taxes . . . . ____________

Administrative Costs . . . . ____________

Energy and Power Costs . . . . ____________

Truck Fuel Costs . . . . ____________

Total Operating Costs . . . . ____________

CODE # ______

Questions Concerning
Wastes Destined for Land Disposal

1. Job Shop ______________ 2. Captive Shop ______________

3. Metal Finishing Processes Operated ______________________________

____

4. Metals Deposited by Electroplating ______________________________

____

5. Number of Production Workers in Metal Finishing ______________

6. Do you treat wastewater before discharge? Yes ______________ No ______________

a. If yes, describe type of treatment ______________________________

7. Do you discharge wastewater to a sewer? Yes ______________ No ______________

a. If yes, where does sewer go? ______________________________

	Sludges	Solvents	Other Process Wastes (Dusts, Abrasives, Anode Bags, etc)	Spent Baths, Concentrated Solutions
8. Quantity/Month				
9. Disposal Method				
a. Sewer				
b. Contractor/Hauler				
c. Lagoon				
d. Landfill				
e. Reclaimer				
f. General Trash				
10. Disposal Cost per Month (include sewer charges, if paid)				
a. Sewer costs				
b. Hauling Costs				

11. Please attach a copy of available data on analysis of sludges and name the chemicals in the wastes listed above (solvents, etc) or describe classification as to origin and frequency below. ______________________________

____

____

FIGURE A-3. FOLLOW-UP TELEPHONE QUESTIONNAIRE

Telephone Survey. The selected treatment and disposal contractors were contacted by telephone over a period of 5 weeks. The IHWMF- and industry-identified sources dominated the list of attempted contacts. Attempts were made to contact all 25 IHWMF-identified companies meeting the selection criteria; 23 plants were contacted, 16 agreed to permit a visit by contractor personnel, and 7 of the latter were visited.

On the returned NAMF data acquisition forms, as originally received by the contractor, the name of the electroplater or metal finisher supplying data was removed (as agreed). However, the name of the waste contractor was also removed. Upon written request to the NAMF this contractor information was supplied to the program. As the names and addresses of contractors were received, they were screened and selected facilities were contacted (or contact was attempted). The names of 26 industry-identified companies were eventually received (including the names of 5 companies for which there was insufficient information to make a contact); Battelle representatives attempted to contact 11 companies but of these companies 4 agreed to a visit, and 2 were visited. The other 15 companies were not contacted because the industry survey was received late in the program. However, through the one-page NAMF follow-up questionnaire, 13 additional waste contractors were identified and one site was visited. Industry contacts with electroplaters and waste contractors identified 2 additional treatment and/or disposal operations. Both of the latter were contacted; one agreed to a visit and was visited.

The results of the telephone survey plus other information obtained on identified treatment and disposal contractors are presented in Table A-1. The information identified for each plant was divided into The information identified for each plant was divided into four areas: (1) services provided (hauling, treatment, and/or disposal), (2) type of wastes handled (sludge, liquids, solids), (3) service costs, and (4) ultimate disposal method.

TABLE A-1. INFORMATION ON PRIVATE CONTRACTORS WHC

Company Number	EPA Region	Identification Source Number[a]	Company Name	Contact Summary				Company Visited
				Contact Attempted by BCL	Contact Made by BCL	Company Response to Visit Request		
						BCL	EPA	
1	I	1	Crago Company, Inc.	Yes	No			No
2	I, III IV	1	Rollins Environmental Services	Yes	Yes	(b)		No
3	II	1	Recyclind Laboratories	Yes	No			No
4	III	1	American Recovery Corp.	Yes	Yes	Yes(c)	Yes	No
5	III, V, IX	1	Nuclear Engineering Co.	Yes	Yes	Yes(c)	Yes	No
6	III	1	Chem-Fix, Inc.	Yes	Yes	Yes	Yes	No
7	IV, VI	1	Petrolite Corporation	Yes	Yes	No	No	No
8	V	1	Hyon Waste Management Services, Inc.	Yes	Yes	Yes	Yes	No
9	V, VII	1, 2	Conservation Chemical Co.	Yes	Yes	No(d) Yes(e)	Yes Yes	 Yes
10	V	1, 2	Approved Chemical Treatment, Inc.	Yes	Yes	Yes	Yes	Yes
11	V	1, 2	Environmental Waste Control, Inc.	Yes	Ye	Yes	Yes	No
12	V	1, 2	Nelson Chemical Company	Yes	Yes	Yes	Yes	No
13	V	1	Erieway Pollution Control, Inc.	Yes	Yes	Yes	Yes	Yes
14	V	1	Koski Construction Co.	Yes	Yes	Yes		Yes
15	V	1	Systech	Yes	Yes	Yes	Yes	Yes
16	V	1	Rogers Laboratories	Yes	Yes	Yes	Yes	No
17	V	1	Waste Research & Reclamation Co., Inc.	Yes	Yes	No	No	No
18	VI	1	U. S. Pollution Control, Inc.	Yes	Yes	No	No	No
19	VI	1	BioEcology Systems, Inc.	Yes	Yes	Yes	Yes	Yes
20	IX	1	Casmalia Disposal Site	Yes	Yes	Yes(c)	No	Yes
21	IX	1	Chancellor & Ogden, Inc.	Yes	No			No
22	IX	1	Richmond Sanitary Services	Yes	Yes	(c)		No
23	X	1	Wes Con, Inc.	Yes	Yes	Yes	Yes	No

HANDLE ELECTROPLATING AND METAL FINISHING WASTES

Type of Operation			Waste Types Hauled, Treated, or Disposed		Service Cost			Ultimate Type of Disposal Facility	
Haul	Treat	Dispose	Sludges	Liquids	Hauling	Treatment and Disposal	Combined	Landfill	Other-Specify
Yes	No		H-T	H-T					
Yes	Yes	Yes	H-T-D	H-T-D	1¢/gal/ 100 mi	10-20¢/gal		x	Incineration
Yes	Yes	Yes	H-T-D	H-T-D					Incineration
Yes	Yes	Yes	H-T-D	H-T-D				x	Lagoon
Yes	No	Yes	H-D	H-D	$1/mi/ truck	$1.25/ft^3		x	Land burial
No	Yes	No	T	T		4¢/gal			Land cover
No	Yes	Yes	T-D	T-D			$\leqslant$19¢/gal	x	Deep-well injection
No	Yes	Yes	T-D	T-D			3-7¢/gal	x	
No	Yes	Yes	T-D	T-D			3¢/gal CN^--10¢/gal	x	Deep-well injection(d)
Yes	Yes	Yes	H-T-D	H-T-D			10-20¢/gal 40¢/gal CN^-	x	
Yes	Yes	No		H					Sewer
Yes	Yes	No	H-T	H-T			$1.20/lb CN^- 16¢/lb CrO_3	x	Sewer
Yes	Yes	Yes	T-D	H-T-D				x	Chemical solidification landfill cover
Yes	Yes	Yes	H-T-D	H-T-d					Lagoon
No	Yes	No		T		$2.50/lb CN^- $1.25/lb Cr^{+6} + 5¢ gal			Piped to city water treatment plant
Yes	Yes	No		H-T				x	
Yes	Yes	No		H-T					Sewer
Yes	Yes	Yes	D	H-T-D		2.3¢/gal	7.5-13¢/gal	x	Deep-well injection
No	Yes	Yes	D	H-T-D			7-30¢/gal; $0.46-1.51/gal CN^-	x	
No	Yes	Yes	T-D	T-D			1-5¢/gal	x	
Yes	No	Yes	H-D	H-D				x	
Yes	No	Yes	H-D	H-D				x	Lagooning Drum burial
No	No	Yes	D	D		$1.00/ft^3			Burial in old missile sites

TABLE A-1.

				Contact Summary				
						Company Response to Visit Request		
Company Number	EPA Region	Identification Source Number[a]	Company Name	Contact Attempted by BCL	Contact Made by BCL	BCL	EPA	Company Visited
24	X	1	Resource Recovery Corp.	Yes	Yes	Yes	Yes	No
25	X	1	Western Processing Co.	Yes	Yes	No	No	No
26	I	2	Environmental Waste Removal, Inc.	Yes	Yes	No	Yes	No
27	II	2	Gcariello	Yes	No[f]			
28	III	2	Jimon Wrecking Co.	Yes	No[f]			
29	V	2	Interstate Pollution Control	Yes	Yes	Yes	Yes	No
30	V	2	Pollution Corporation of America[g]	Yes	Yes	NA[h]	NA	No
31	V	2	Frinks Sewer Service	Yes	Yes	NA	NA	No
32	V	2	Peter Wallin Company	Yes	No[f]			
33	V	2	Summit National Services	Yes	Yes	Yes	Yes	Yes
34	V	2	Valentine Disposal	Yes	Yes	Yes	Yes	Yes
35	V	4	Warren County Solid Waste Authority	Yes	Yes	Yes	Yes	Yes
36	V	3	Ohio Sanitation Systems, Inc.	Yes	Yes	Yes	Yes	Yes
37	VI	4	Industrial Wastes Sonics International Corp.	Yes	Yes			No
38	IX	2	Oscar Erickson	Yes	Yes	(c)		
39	IX	2	J. & M. Filtering	Yes	Yes	Yes	Yes	No
40	IX	2	Capri Pumping Service	Yes	No[f]			
41	IX	3, 1	Industrial Tank, Inc.	Yes	Yes	Yes	Yes	No
42		2	Pats Carting (NAMF-163)	No				
43		2	Smithen Sanitation (NAMF-629)	No				
44	III	2	Bradford Sewerage Works	No				
45	IV	2	Golden Strip Septic Tank Service	No				
46	V	2	Morris Roth	No				
47	V	2	City of Mansfield	No				

(Continued)

Type of Operation			Wsste Types Hauled, Treated, c Disposed		Service Cost			Ultimate Type of Disposal Facility	
Haul	Treat	Dispose	Sludges	Liquids	Hauling	Treatment and Disposal	Combined	Landfill	Other-Specify
Yes	No	Yes		R-D			2.5¢/gal	x	Ponding Drum burial
No	Yes	No	T	T					Claims no discharge or land disposal
Yes	Yes	Yes	H-T-D	H-T-D			~15¢/gal		Stock pile sludges on land
Yes	Yes	Yes	H-D	H-T-D			15-20¢/gal	x	Ship sludges to outside disposal
Yes	No	Yes	H-D	x				x	
Yes	No	NO		H-T	3¢/gal	6¢/gal	9¢/gal		Trucks wastes to outside disposal
Yes	Yes			H-T				x	Incinerator-residues landfilled
Yes	No	Yes	H-D	H-D				x	
No	No	Yes	D					x	
Yes	Yes	Yes	H-T-D	H-T-D	$30/hr	$5/ton landfilled		x	
		Yes		D					Deep-well injection
Yes	Yes	No		H-T-D		2¢/gal		x	
	Yes								
Yes	Yes	Yes	D	H-T-D			2-5¢/gal		Ponding, Drum burial; Incineration
Yes			H						
Yes			H						
			H						
		Yes							

TABLE A-1.

Company Number	EPA Region	Identification Source Number[a]	Company Name	Contact Summary				
				Contact Attempted by BCL	Contact Made by BCL	Company Response to Visit Request BCL	EPA	Company Visited
48	V	2	H & H Industries	No				
49	V	2	Region's Rubbish	No				
50	V	2	Udulite Corporation	No				
51	V	2	Browning Ferrous Industries	No				
52	V	2	Apple Canton "Egg"	No				
53	V	2	Busco	No				
54	IX	2	Tandy Pumping Service	No				
55	IX	2	M. C. Nottingham (NAMF-339)	No				
56	IX	2	George F. Cagey	No				
57	I	3	Hitchcock Gas Engine Co.	No				
58	II	3	South Side Carting	No				
59	II	3	Jamaica Ash & Rubbish	No				
60	II	3	Air Vac	No				
61	II	3, 1	Chemtrol	No				
62	III	3	Lundmark Septic Tank	No				
63	IV	3	Rubin Construction Co.	No				
64	V	3	Burrows Sanitation	No				
65	V	3	George Miller & Sons	No				
66	V	3	Regional Services, Inc.	No				
67	V	3	Wayne Dean	No				

(a) Identification Source Number:
(1) Farb, D. and S. D. Ward, "An Inventory of Hazardous Waste Management Facilities", USEPA, OSWM (draft report).
(2) National Association of Metal Finishers (NAMF) questionnaire.
(3) BCL questionnaires.
(4) Contact with plater, metal finisher, or private contractor.
(b) Showed reluctance to allow visit – but did not refuse.

(Continued)

Type of Operation			Waste Types Hauled, Treated, or Disposed		Service Cost			Ultimate Type of Disposal Facility	
Haul	Treat	Dispose	Sludges	Liquids	Hauling	Treatment and Disposal	Combined	Landfill	Other-Specify
Yes									
Yes			H	H					
Yes	Yes	Yes	H-T-D	H-T-D					
Yes			H						
Yes			H						
Yes									
Yes									
Yes			H	H					
Yes			H						
Yes									
Yes									
Yes									
Yes	Yes	Yes	T	T-D				x	
Yes	Y			H-T					
		Yes	D						
No		Yes	D					x	
Yes		No	H					x	

(c) Requested letter from EPA before allowing visit.
(d) Gary, Indiana, plant.
(e) Kansas City, Missouri, plant.
(f) When contact attempted, no telephone listing could be found.
(g) Sold to Browning Ferrous Industries.
(h) NA = Not applicable -- contractor does not handle wastes characteristic of electroplating or metal-finishing wastes.

APPENDIX B

MODEL PLANT A (38 EMPLOYEES)

APPENDIX B - MODEL PLANT A (38 EMPLOYEES)

PART I. TOTAL INDUSTRY WASTES FROM MODEL ELECTROPLATING AND METAL FINISHING PLANT

INTRODUCTION

The many metals that are deposited from aqueous solutions of different anionic species and concentrations on a multitude of basis materials (metallic or nonmetallic), requiring different process steps in the production operations appears to make the task of designating a plant as a "model plant", very formidable. The theoretical development of such a plant, of course, must have some basic pertinent factors incorporated, in order for the data that is derived from this plant to be meaningful and applicable to the "industry" as a whole.

The selection of the plant operations was made from the knowledge that at least two thirds of all metal finishing involves the deposition of copper, nickel, chromium, and zinc. The majority of products are made of ferrous or copper-base alloys. Other important operations, such as phosphating, electroless nickel plating, and anodizing, were also made part of the plant production because they are frequently occurring processes with large size installations, and they also pose specific waste treatment problems. Precious metals deposition processes have been omitted from the plant because where these metals are used in significant quantities, recovery rather than disposal is practiced. Of course, preplating operations still produce wastes, but these are not significantly different to handle than the wastes generated from the preplating operations of the included processes. The final determination of how many processes could be operated in the model plant was the limitation of its size.

Average plant size was found from the data on Industry Characterization to be one having from 25 to 50 employees. In the model plant, the type and quantity of work is believed to be sufficiently carried out by 30 production employees. Twelve people are used for pre- and post-plating operation such as grinding, polishing, etc. A total of eight management, supervisory, and clerical personnel were added to complete the plant capabilities.

The following calculations and discussions are divided into two units, each one being an entity in itself so that conclusions arrived from each unit may be applied to the "industry" in part or as a total. The two units are

(A) Determination of the quantity of waste generated in an electroplating and metal finishing facility that uses combined chemical treatment and neutralization/precipitation techniques, and

(B) Determination of the quantity of waste generated in an electroplating and metal finishing facility from mechanical pre- and postplating operations, solution and equipment maintenance, and from organic solvents.

(A) DETERMINATION OF THE QUANTITY OF WASTE GENERATED IN AN ELECTROPLATING AND METAL FINISHING FACILITY THAT USES COMBINED CHEMICAL TREATMENT AND NEUTRALIZATION/PRECIPITATION TECHNIQUES

Model Plant Operations

A summary description of the nine processing lines in the plant, along with a description of the work assignments for the 30-man plant and eight supervisory employees are provided in Table B-1. The assumed production rate presented in the second column of the table shows the physical workpiece area processed in each line. The processing rate reflects the number of operations [i.e., the number of different metallic plates or coatings applied to the same part (e.g., Cu-Ni-Cr plating = three operations; zinc plate plus chromating = two operations)] carried out on a workpiece. The water volume used for the rinsing operations from the divided processing streams for acid/alkali, cyanide, and chromium is summarized for each line.

Detailed diagrams and descriptions of the nine processing lines in the model plant are presented in Table B-2, lines one through nine. Data on bath volumes, bath composition, dump frequency, drag out, rinse water flows, etc., for the various cleaning, pickling, plating, and other processing steps are given. The rinse water use is calculated from the assumption that a certain maximum quantity of dissolved solids, generally 37 mg/l in rinses following metal-electrodeposition steps and 750 mg/l for rinses following cleaning and dipping operations, has been established as a good rinsing practice(B-1). The water volume is then dependent on the number of rinses and how they are arranged, i.e., countercurrent or single, as well as the solution drag-out rate. Drag-out rates may vary more than one magnitude, depending on size and shape of the part and rack, and solution viscosity. In the calculations that follow, a drag-out rate of 1.0 and 1.75 l/m^2 area processed (3 and 5 gal/1000 sq ft) for rack and barrel plating respectively has been assumed for the purpose of taking into account the multitude of simple- and complex-shaped parts that are processed through a plating line. No allowances were made for the use of save rinses of any kind so that the loss of plating chemicals from solutions would be near its maximum. A rinsing efficiency factor of 0.7 is used to take into account solution effects which are different from those obtained when the parts are moved in water only. This factor is commonly applied in practice.

As an example, for a cleaning solution having a make-up concentration of 8 oz/gal (60,000 mg/l) consisting of a proprietary cleaner used in a rack-plating line processing 560 m^2/day (6024 sq ft/day), the drag out is 3.0 gal/1000 sq ft x 6.024 sq ft/day = 18.1 gal/day.

TABLE B-1. MODEL ELECTROPLATING PLANT OPERATIONS

Line or Operation	Assumed Production Rate, m^2/day	Assumed Production Rate, ft^2/day	Processing Rate, m^2/day	Processing Rate, ft^2/day	Employees Rack, Unrack Plating, etc.	Others
1) Automatic Rack Cu(CN)-Ni-Cr	560	6,024	1,680	18,072	7	
2) Manual Rack Cu(CN)-Ni-Cr	160	1,720	480	5,160	3	
3) Automatic Rack Zn(CN) + Chromating	800	8,608	1,600	17,216	5	
4) Automatic Barrel Zn(CN) + Chromating	480	5,160	960	10,320	3	
5) Manual Barrel Cd(CN) + Chromating	160	1,720	320	3,440	1	
6) Manual Rack Hard Cr	80	864	80	864	1	
7) Manual Rack Al Anodizing (+ Bright Dip + Nickel - Acetate Seal)	600	6,456	1,800	19,368	6	
8) Automatic Barrel Zn Phosphating	400	4,304	400	4,304	2	
9) Manual Electroless Nickel Rack Plating	160	1,720	160	1,720	2	
Combined Lines	3,400	36,576	7,480	80,464	30	8 (See Below)

Other Employees

Supervision (Plating)	1
Supervision + W.T.	1
Lab Analysis (W.T. + Plating)	1
Rack-Repair-Stripping	1
Maintenance	1
Misc. Job in Plating Shop	1
Clerical	2
Subtotal	8
Total	38

TABLE B-2. LINE 1, AUTOMATIC RACK Cu(CN)-Ni-Cr

Drag out: 3.0 gal/1000 sq ft
Area plated per day: 6024 sq ft
Drag out rate: 3.0 x 6.024 = 18.1 gal/day
Work pieces plated: Steel 70 percent
70/30 Brass 30 percent

Process Steps

(1) Hot Alkali Soak Clean

Conc.	8 oz/gal
Tank volume	2000 gal
Dump cycle	25 days

(2) Single Rinse, flow $= \frac{(60,000)(18.1)^{*}}{(750)(0.7)} = 2070$ gal/day

(3) Electrolytic Anodic Clean [same as (1)]

(4) Single Rinse, flow = 2070 gal/day

(5) Sulfuric Acid Pickle

Conc.	45 g/l
Tank volume	500 gal
Dump cycle	10 days

(6) Single Rinse, flow $= \frac{(45,000)(18.1)}{(750)(0.7)} = 1550$ gal/day

(7) Copper Cyanide Plate

Conc.	CuCN	5.0 oz/gal
	NaCN	7.0 "
	NaOH	0.5 "
	Na_2CO_3	2.0 "

(8) Countercurrent Rinse
2 stations, flow $= \left(\frac{109,000}{37}\right)^{1/2} \left(\frac{18.1}{0.7}\right) = 1400$ gal/day

(9) Sulfuric Acid Dip

Conc.	107 g/l
Tank volume	500 gal
Dump cycle	10 days

(10) Single Rinse, flow $= \frac{(107,000)(18.1)}{(750)(0.7)} = 3690$ gal/day

---

* 60,000 is total salt concentration, mg/l
18.1 is the drag out rate, gal/day
750 allowable salt concentration in rinse, mg/l
0.7 rinsing efficiency of 70 percent

TABLE B-2. LINE 1 (Continued)

(11) Nickel Plate

Conc. $NiSO_4 \cdot 6H_2O$ 40 oz/gal
$NiCl_2 \cdot 6H_2O$ 6 "
H_3BO_3 5 "

(12) Countercurrent Rinse

2 stations, flow $= \left(\frac{248,000}{37}\right)^{1/2} \left(\frac{18.1}{0.7}\right) =$ 2120 gal/day

(13) Chromium Plate

Conc. CrO_3 45 oz/gal
H_2SO_4 0.45 oz/gal

(14) Countercurrent Rinse

2 stations, flow $= \left(\frac{340,000}{15}\right)^{1/2} \left(\frac{18.1}{0.7}\right) =$ 3900 gal/day

TABLE B-2. LINE 2, MANUAL RACK Cu(CN)-Ni-Cr

Drag out:	3.0 gal/1000 sq ft
Area plated per day:	1720 sq ft
Drag out rate:	3.0 x 1.72 = 5.16 gal/day
Rinsing efficiency:	70 percent
Work pieces plated:	Steel 70 percent 70/30 Brass 30 percent

Process Steps

(1) Hot Alkali Soak Clean

Conc.	8 oz/gal
Tank volume	600 gal
Dump cycle	25 days

(2) Single Rinse

$$\text{Rinse flow} = \frac{(60{,}000)(5.16)}{(750)(0.7)} = 590 \text{ gal/day}$$

(3) Electrolytic Anodic Clean

Conc.	8 oz/gal
Tank volume	300 gal
Dump cycle	20 days

(4) Single Rinse

Rinse flow = same as (2) = 590 gal/day

(5) Sulfuric Acid Dip

Conc.	45 g/l
Tank volume	200 gal
Dump cycle	10 days

(6) Single Rinse

$$\text{Rinse flow} = \frac{(45{,}000)(5.16)}{(750)(0.7)} = 450 \text{ gal/day}$$

(7) Copper Cyanide

Conc.	CuCN	5.0 oz/gal
	NaCN	7.0 "
	NaOH	0.5 "
	Na_2CO_3	2.0 "

(8) Countercurrent Rinse

$$\text{Rinse flow} = \left(\frac{109{,}000}{37}\right)^{1/2}\left(\frac{5.16}{0.7}\right) = 400 \text{ gal/day}$$

(9) Sulfuric Acid Dip

Conc.	107 g/l
Tank volume	200 gal
Dump cycle	10 days

(10) Single Rinse

$$\text{Rinse flow} = \frac{(107{,}000)(5.16)}{(750)(0.7)} = 1050 \text{ gal/day}$$

TABLE B-2. LINE 2 (Continued)

(11) Nickel Plate

Conc.		
	$NiSO_4 \cdot 6H_2O$	40 oz/gal
	$NiCl_2 \cdot 6H_2O$	6 "
	H_3BO_3	5 "

(12) Countercurrent Rinse, 2 stations

$$\text{Rinse flow} = \left(\frac{248,000}{37}\right)^{1/2}\left(\frac{5.16}{0.7}\right) = 610 \text{ gal/day}$$

(13) Chrome Plate

Conc.		
	CrO_3	45 oz/gal
	H_2SO_4	0.45 "

(14) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{340,000}{15}\right)^{1/2}\left(\frac{5.16}{0.7}\right) = 1110 \text{ gal/day}$$

TABLE B-2. LINE 3, AUTOMATIC RACK ZINC (CN)

Drag out: 3.0 gal/1000 sq ft
Area plated per day: 8608 sq ft
Drag out rate: 3.0 x 8.608 = 25.8 gal/day
Rinsing efficiency: 70 percent
Workpieces plated: Steel

Process Steps

(1) Electrolytic Anodic Clean

Conc.	8 oz/gal
Tank volume	500 gal
Dump cycle	15 days

(2) Single Rinse

$$\text{Flow} = \frac{(60{,}000)(25.8)}{(750)(0.7)} = 2950 \text{ gal/day}$$

(3) Concentrated Hydrochloric Acid Dip

Conc.	111 g/l
Tank volume	250 gal
Dump cycle	25 days

(4) Single Rinse, $\text{flow} = \frac{(111{,}000)(25.8)}{(750)(0.7)} = 5460 \text{ gal/day}$

(5) Caustic Dip

Conc.	NaOH 1 oz/gal
Tank volume	250 gal
Dump cycle	5 days

(6) Zinc Cyanide Plate

Conc.	Zn as metal	40 g/l
	NaOH	90 "
	NaCN	90 "

(7) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{220{,}000}{37}\right)^{1/2} \left(\frac{25.8}{0.7}\right) = 2850 \text{ gal/day}$$

(8) Chromate Dip

Conc.	$Na_2Cr_2O_7 \cdot 2H_2O$	2 oz/gal
	HNO_3	1 oz/gal
Tank volume	250 gal	
Dump cycle	5 days	

(9) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{20{,}700}{37}\right)^{1/2} \left(\frac{25.8}{0.7}\right) = 880 \text{ gal/day}$$

TABLE B-2. LINE 4, AUTOMATIC BARREL ZINC (CN)

Drag out:	5.0 gal/1000 sq ft
Area plated per day:	5160 sq ft
Drag out rate:	5 x 5.16 = 25.8 gal/day
Rinsing efficiency:	70 percent
Workpieces plated:	Steel

Process Steps

(1) Hot Alkali Soak Clean

Conc.	8 oz/gal
Tank volume	600 gal
Dump cycle	10 days

(2) Single Rinse, flow $= \frac{(60,000)(25.8)}{(750)(0.7)} = 2950$ gal/day

(3) Concentrated Hydrochloric Acid Dip

Conc.	111 g/1
Tank volume	200 gal
Dump cycle	15 days

(4) Single Rinse, flow $= \frac{(111,000)(25.8)}{(750)(0.7)} = 5460$ gal/day

(5) Caustic Dip

Conc.	NaOH 1 oz/gal
Tank volume	200 gal
Dump cycle	5 days

(6) Zinc Cyanide Plate

Conc.	Zn as metal	40 g/1
	NaOH	90 "
	NaCN	90 "

(7) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{220,000}{37}\right)^{1/2} \left(\frac{25.8}{0.7}\right) = 2850 \text{ gal/day}$$

(8) Nitric Acid Dip

Conc.	50 g/1
Tank volume	200 gal
Dump cycle	5 days

(9) Chromate Dip

Conc.	$Na_2Cr_2O_7 \cdot 2H_2O$	2 oz/gal
	HNO_3	1 oz/gal
Tank volume	200 gal	
Dump cycle	5 days	

(10) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{20,700}{37}\right)^{1/2} \left(\frac{25.8}{0.7}\right) = 880 \text{ gal/day}$$

TABLE B-2. LINE 5, MANUAL BARREL CADMIUM (CN)

Drag out: 5.0 gal/1000 sq ft
Area plated per day: 1720 sq ft
Drag out rate: 5 x 1.72 = 8.6 gal/day
Workpieces plated: Steel

Process Steps

(1) Cathodic Alkaline Clean
    Conc. 8 oz/gal
    Tank volume 400 gal
    Dump cycle 10 days

(2) Single Rinse, Flow $= \frac{(60{,}000)(8.6)}{(750)(0.7)} = 990$ gal/day

(3) Hydrochloric Acid Dip
    Conc. 111 g/1
    Tank volume 200 gal
    Dump cycle 10 days

(4) Single Rinse, Flow $= \frac{(111{,}000)(8.6)}{(750)(0.7)} = 1820$ gal/day

(5) Caustic Dip
    Conc. NaOH 15 g/1
    Tank volume 200 gal
    Dump cycle 5 days

(6) Single Rinse, Flow $= \frac{(15{,}000)(8.6)}{(750)(0.7)} = 250$ gal/day

(7) Cadmium Plate
    Conc. Cd 2.66 oz/gal
    NaCN 13.3 "
    NaOH 1.9 "
    Na_2CO_3 7.0 "

(8) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{186{,}000}{37}\right)^{1/2}\left(\frac{8.6}{0.7}\right) = 880 \text{ gal/day}$$

(9) Chromate Dip
    Conc. $Na_2Cr_2O_7 \cdot 2H_2O$ 2 oz/gal
    HNO_3 1 oz/gal
    Tank volume 200 gal
    Dump cycle 10 days

(10) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{20{,}700}{37}\right)^{1/2}\left(\frac{8.6}{0.7}\right) = 500 \text{ gal/day}$$

TABLE B-2. LINE 6, MANUAL RACK HARD CHROMIUM

Drag out: 3.0 gal/1000 sq ft
Area plated per day: 864 sq ft
Drag out rate: $3 \times 0.864 = 2.60$ gal/day
Rinsing efficiency: 70 percent
Workpieces plated: Steel

Process Steps

(1) Cathodic Alkaline Clean
    Conc. 8 oz/gal
    Tank volume 200 gal
    Dump cycle 20 days

(2) Single Rinse, flow $= \frac{(60{,}000)(2.60)}{(750)(0.7)} = 300$ gal/hr

(3) Anodic Sulfuric Acid Treatment
    Conc. 960 g/l
    Tank volume 200 gal
    Dump cycle 60 days

(4) Two Series Rinses

$$\text{Flow} = \left(\frac{960{,}000}{15}\right)^{1/2}\left(\frac{2.60}{0.7}\right) = 1880 \text{ gal/day}$$

(5) Chromium Plate
    Conc. CrO_3 45 oz/gal
    H_2SO_4 0.5 oz/gal

(6) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{340{,}000}{15}\right)^{1/2}\left(\frac{2.60}{0.7}\right) = 560 \text{ gal/day}$$

TABLE B-2. LINE 7, MANUAL RACK ANODIZING

Drag out: 3 gal/1000 sq ft
Area plated per day: 6456 sq ft
Drag out rate: 3 x 6.456 = 19.37 gal/day
Rinsing efficiency: 70 percent

Three save rinses on bright dips to recover 80 to 90 percent of drag out. The adjusted value of 206 g/l is used. The saved solutions are sold for fertilizer.

Workpieces: Aluminum

Process Steps

(1) Hot Alkali Soak Clean
    Conc. 8 oz/gal
    Tank volume 800 gal
    Dump cycle 15 days

(2) Single Rinse, flow $= \frac{(60,000)(19.37)}{(750)(0.7)} = 2200$ gal/day

(3) Caustic Etch
    Conc. NaOH 53 g/l
    Tank volume 400 gal
    Dump cycle 7.5 days

(4) Single Rinse, flow $= \frac{(53,000)(19.37)}{(750)(0.7)} = 1960$ gal/day

(5) Nitric Acid Desmut
    Conc. 100 g/l
    Tank volume 400 gal
    Dump cycle 20 days

(6) Single Rinse, flow $= \frac{(100,000)(19.37)}{(750)(0.7)} = 3680$ gal/day

(7) Bright Dip
    Conc. H_3PO_4 67 percent by volume
    HNO_3 3 percent by volume

(8) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{206,000}{37}\right)^{1/2}\left(\frac{19.37}{0.7}\right) = 2080 \text{ gal/day}$$

(9) Anodize
    Conc. H_2SO_4 165 g/l
    Tank volume 3000 gal
    Dump cycle 20 days

TABLE B-2. LINE 7 (Continued)

(10) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{165{,}000}{37}\right)^{1/2} \left(\frac{19.37}{0.7}\right) = 1840 \text{ gal/day}$$

(11) Nickel Acetate Seal

Conc.	$Ni(C_2H_3O_2)_2 \cdot 4H_2O$	10 g/1
Tank volume	400 gal	
Dump cycle	5 days	

(12) Single Rinse, flow $= \frac{(10{,}000)(19.37)}{(100)(0.7)} = 2760$ gal/day

TABLE B-2. LINE 8, AUTOMATIC BARREL ZINC PHOSPHATING

Drag out:	5 gal/1000 sq ft
Area plated per day:	4304 sq ft
Drag out rate:	5 x 4.304 = 21.52 gal/day
Rinsing efficiency:	70 percent
Workpieces:	Steel

Process Steps

(1) Hot Alkali Soak Clean

Conc.	8 oz/gal
Tank volume	250 gal
Dump cycle	20 days

(2) Single Rinse, flow $= \frac{(60,000)(21.52)}{(750)(0.7)} = 2460$ gal/day

(3) Hydrochloric Acid Pickle

Conc.	75 g/1
Tank volume	250 gal
Dump cycle	10 days

(4) Single Rinse, flow $= \frac{(75,000)(21.52)}{(750)(0.7)} = 3080$ gal/day

(5) Zinc Phosphate

Conc.	$H_3PO_4 \cdot Zn_3(PO_4)_2$	42 g/1
Tank volume	250 gal	
Dump cycle	15 days	

(6) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{42,000}{37}\right)^{1/2} \left(\frac{21.52}{0.7}\right) = 1040 \text{ gal/hr}$$

(7) Hot Dip Seal

Conc.	CrO_3	0.25 g/1
Tank volume	250 gal	
Dump cycle	5 days	

TABLE B-2. LINE 9, MANUAL ELECTROLESS RACK NICKEL

Drag out:	3 gal/1000 sq ft
Area plated per day:	1720 sq ft
Drag out rate:	3 x 1.72 = 5.16 gal/day
Rinsing efficiency:	70 percent
Workpieces plated:	Steel

Process Steps

(1) Hot Alkali Soak Clean

Conc.	8 oz/gal
Tank volume	200 gal
Dump cycle	10 days

(2) Single Rinse, flow $= \frac{(60,000)(5.16)}{(750)(0.7)} = 590$ gal/day

(3) Hydrochloric Acid Dip

Conc.	240 g/l
Tank volume	200 gal
Dump cycle	15 days

(4) Single Rinse, flow $= \frac{(240,000)(5.16)}{(750)(0.7)} = 2360$ gal/day

(5) Electroless Nickel Plate

Conc.	$NiSO_4 \cdot 7H_2O$	30 g/l
	$NaH_2PO_2 \cdot 2H_2O$	10 "
	$NaC_2H_3O_2 \cdot 3H_2O$	10 "

(6) Countercurrent Rinse, 2 stations

$$\text{Flow} = \left(\frac{34,400}{37}\right)^{1/2} \left(\frac{5.16}{0.7}\right) = 230 \text{ gal/day}$$

The water use required for a single station rinse following the cleaning is

$$\frac{60{,}000 \text{ mg/l} \times 18.1 \text{ gal/day}}{750 \text{ mg/l} \times 0.7} = 2120 \text{ gal/day} = 8025 \text{ l/day.}$$

Having a countercurrent rinse with two tanks would reduce the water use to

$$\left(\frac{60{,}000}{750}\right)^{1/2} \left(\frac{18.1}{0.7}\right) = 230 \text{ gal/day} = 875 \text{ l/day.}$$

Waste-Treatment Procedures

Principal Considerations

All the processing rates and material balances will be presented on a daily basis for the model plant. This will permit ready conversion of the data and results to another time basis if desired.

Combined chemical treatment and neutralization/precipitation techniques will be employed in the model plant. The dumps will be presumed to be metered in at a designated rate into the the rinse streams. The main plating baths will not be dumped; however, the alkaline cleaners and dips, chromating, anodizing, and phosphating baths are dumped on a periodic basis (see Figure B-1).

The rinse waters and dumps from the various processing operations on the lines will be segregated into three main streams as follows:

(1) Cyanide
(2) Chromium
(3) Acid/Alkali.

A schematic diagram showing materials flow as well as the overall waste-treatment scheme for handling the effluents from the model plant electroplating and metal finishing plant is presented in Figure B-1.

Although many of the alkaline cleaners used in electroplating plants are proprietary mixtures, the individual cleaner compositions employed in the model plant (Table B-3) are considered representative of actual practice. The particular cleaner composition used will be indicated in the calculations carried out on the individual lines.

It will be assumed that 25 percent of the alkaline cleaner ingredients are used up in reactions with greases, oil, etc., softening water, breaking up esters, etc., to form precipitates or other materials which settle out as sludges. In the model plant, these sludges will be included with the liquid cleaner dumps going to the waste-treatment plant. These sludges will be considered to represent a portion of the overall solid waste in the underflow from the clarifier.

PROCESS LINES	WASTE STREAMS	RINSE AND DUMP VOLUME, gal/day
Line 1 Cu-Ni-Cr (Auto.)	CuCN	1,400
	Ni	2,120
	Cr	3,900
	A/A *	9,640
Line 1 Cu-Ni-Cr	CuCN	400
	Ni	610
	Cr	1,100
	A/A	3,370
Line 3 $Zn(CN)_2$ (Auto.)	ZnCN	2,850
	Chromate	930
	A/A	8,510
Line 4 $Zn(CN)_2$	$Zn(CN)_2$	2,850
	Chromate	920
	A/A	8,550
Line 5 $Cd(CN)_2$	$Cd(CN)_2$	880
	Chromate	320
	A/A	3,160
Line 6 Cr	Cr	560
	A/A	2,200
Line 7 Anodize	Bright Dip	2,080
	Anodize	2,000
	Ni Acet.	2,840
	A/A	7,970
Line 8 Phosphate	Zn Phosphate	1,060
	A/A	5,580
	CrO_3 Seal	50
Line 9 Electro-less Ni	Ni	230
	A/A	2,990

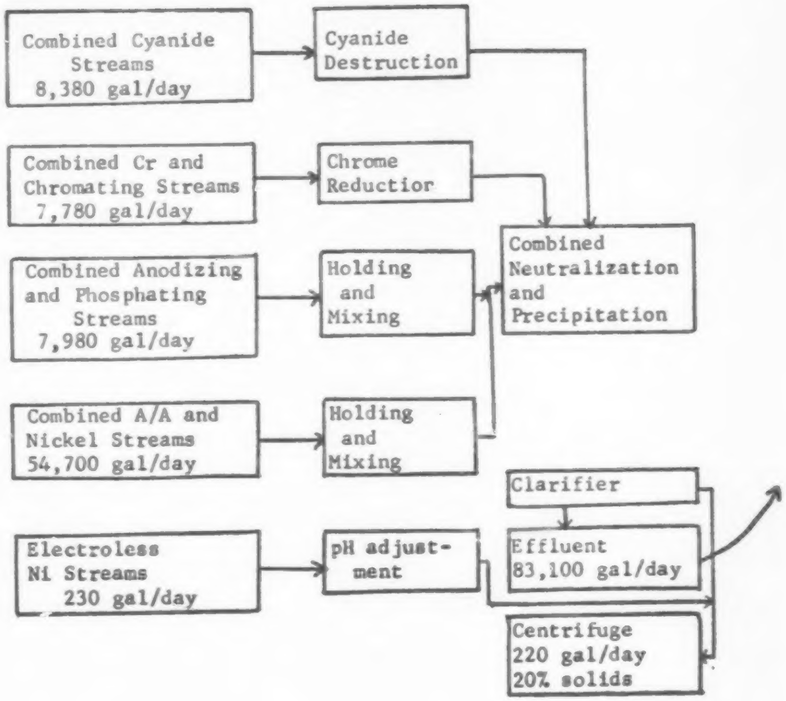
Combined Cyanide Streams 8,380 gal/day
Cyanide Destruction
Combined Cr and Chromating Streams 7,780 gal/day
Chrome Reductior
Combined Anodizing and Phosphating Streams 7,980 gal/day
Holding and Mixing
Combined A/A and Nickel Streams 54,700 gal/day
Holding and Mixing
Combined Neutralization and Precipitation
Clarifier
Electroless Ni Streams 230 gal/day
pH adjust-ment
Effluent 83,100 gal/day
Centrifuge 220 gal/day 20% solids

FIGURE B-1. FEATURES OF SLUDGE GENERATION IN THE MODEL PLANT

* A/A = acid/alkali.

TABLE B-3. REPRESENTATIVE ALKALINE CLEANER COMPOSITIONS

Material	Composition, weight percent			
	Typical Soak Cleaner	Soak Cleaner for Aluminum	Electrocleaner for Steel	Electrocleaner for Steel, Cu, Zn, or Brass
Sodium hydroxide, NaOH	35	0	50	35
Anhydrous sodium metasilicate, Na_2SiO_3	25	40	40	40
Sodium carbonate, Na_2CO_3	22	45	4	13
Trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$	12	10	5	10
Surfactant	6	5	1	2

Calculations Related to Cleaners, Acid Dips, and Processing Baths That Are Periodically Dumped

The calculations that follow deal with cleaners, acid dips, caustic etches, and other processing baths that are used up during the overall electroplating and metal finishing operations carried out on the various process lines; the spent baths are periodically dumped, according to the schedules of Table B-2.

Detailed calculations are given for the process steps of line one (Table B-2) to exemplify the assumptions made and to illustrate the general techniques employed in material balance relevant to rinsewaters and the dumps of the various processing solutions.

Hot Alkali Soak Clean

Make-up concentration = 8 oz/gal = 60 g/l

Cleaner Constituent (Table B-3)	Composition				
	Original			Residual 75 percent	
	Weight Percent	g/l	oz/gal	g/l	oz/gal
Sodium hydroxide, NaOH	35	21.0	2.8	15.8	2.10
Sodium metasilicate, Na_2SiO_3	25	15.0	2.0	11.3	1.50
Sodium carbonate, Na_2CO_3	22	13.2	1.76	9.9	1.32
Trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$	12	7.2	0.96	5.4	0.72
Surfactant	6	3.8	0.5	2.9	0.38

Drag out rate: 18.1 gal/day = 68.5 l/day
Dump cycle: 25 days
Tank volume: 2000 gal = 7570 l
Dump rate: 80 gal/day = 303 l/day

Daily Amounts of Cleaner Constituents in Drag Out and Dump Stream

NaOH: 80 gal/day dump rate × 2.10 oz/gal of NaOH = 168 oz/day
= 10.40 lb/day = 4.70 kg/day

Na_2CO_3: (80)(1.32) = 106 oz/day = 6.64 lb/day = 3.04 kg/day

Na_2SiO_3: (80)(1.50) = 120 oz/day = 7.52 lb/day = 3.44 kg/day

$Na_3PO_4 \cdot 12H_2O$: (80)(0.78) = 62.4 oz/day = 3.92 lb/day = 1.76 kg/da

Electrolytic Anodic Clean
(Steel and Nonferrous Metals)

Make-up concentration = 8 oz/gal = 60 g/l

Cleaner Constituent	Composition: Original Weight Percent	Original g/l	Original oz/gal	Residual 75 percent g/l	Residual 75 percent oz/gal
Sodium hydroxide, NaOH	35	21.0	2.8	15.8	2.10
Sodium metasilicate, Na_2SiO_3	40	24.0	3.2	16.8	2.40
Sodium carbonate, Na_2CO_3	13	7.8	1.04	5.9	0.78
Trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$	10	6.0	0.80	4.5	0.60
Surfactant	2	1.2	0.16	0.9	0.12

Drag out rate:	18.1 gal/day = 68.5 l/day
Dump cycle:	15 days
Tank volume:	1000 gal = 3785 l
Dump rate:	66.7 gal/day = 252 l/day

Daily Amounts in Drag Out and Dump Stream

NaOH: (66.7)(2.10) = 140 oz/day = 8.72 lb/day = 3.92 kg/day

Na_2CO_3: (66.7)(0.78) = 3.28 lb/day = 1.52 kg/day

Na_2SiO_3: (66.7)(2.4) = 160 oz/day = 10.0 lb/day = 4.56 kg/day

$Na_3PO_4 \cdot 12H_2O$: (66.7)(0.60) = 32 oz/day = 2.48 lb/day = 1.12 kg/day

Sulfuric Acid Pickle

Drag out rate:	18.1 gal/day = 68.5 l/day
Dump cycle:	10 days
Tank volume:	500 gal = 1895 l
Dump rate:	50 gal/day = 190 l/day

The original acid concentration of 6 oz/gal (45 g/l) will be maintained by fresh additions of acid to the tank twice a day; the acid added will be equivalent to the acid leaving in the drag out.

It will also be assumed that 15 percent of the acid will be used up in pickling the metal parts being processed which are 70 percent steel and 30 percent brass (70 percent Cu, 30 percent Zn).

According to the reaction

$$Fe^{o} + 2H^{+} \longrightarrow Fe^{2+} + H_2\uparrow$$

one gram of steel (Fe) reacts with 1.76 g of H_2SO_4 having a molecular weight of 98.08 g/mole. Similarly, 1 g 70/30 brass reacts with 1.53 g of H_2SO_4 for a molecular weight of 64.09 g/mole, determined as follows

$$\begin{aligned} \text{Cu - } 63.54 \text{ g/mole} \times 0.70 \text{ percent} &= 44.48 \\ \text{Zn - } 65.38 \text{ g/mole} \times 0.30 \text{ percent} &= \underline{19.61} \\ \text{70/30 brass} &= 64.09 \end{aligned}$$

The amount of 85 percent (38.25 g/l) of the unreacted sulfuric acid that leaves in the dump and drag out stream is as follows:

(Dump rate + Drag out rate in gal/day)(H_2SO_4 conc. in g/l)
(3.785 l/gal)

(50 + 18.1)(38.25)(3.785) = 9859 g/day = 9.859 kg/day = 21.76 lb/day

The amount of various metals in the dump and drag out stream which have been dissolved with 15 percent (6.75 g/l) of the acid

(50 + 18.1)(6.75)(3.785) = 1740 g/day = 1.740 kg/day = 3.84 lb/day

of sulfuric acid, are

$$\frac{(1740)(0.70)}{1.76} = 692 \text{ g/day} = 0.692 \text{ kg/day} = 1.528 \text{ lb/day of iron}$$

$$\frac{(1740)(0.30)}{1.53} = 341 \text{ g/day} \begin{cases} 239 \text{ g/day} = 0.239 \text{ kg/day} \\ \qquad\qquad\; = 0.528 \text{ lb/day of copper} \\ 102 \text{ g/day} = 0.102 \text{ kg/day} \\ \qquad\qquad\; = 0.224 \text{ lb/day of zinc} \end{cases}$$

Sulfuric Acid Dip
(After Cu(CN) Plating)

This dip will be assumed to dissolve a negligible amount of copper plate; no fresh additions of acid are made.

Drag out rate: 18.1 gal/day = 68.5 l/day
Dump cycle: 10 days
Tank volume: 500 gal = 1895 l
Dump rate: 50 gal/day = 190 l/day

The quantity of acid going to the dump and drag out stream is as follows:

(50)(107)(3.785) = 20250 kg/day = 20.25 kg/day = 44.70 lb/day of sulfuric acid

Calculations Related to Chemical Losses from Plating Baths

Drag out with the workpieces and racks constitutes the major loss of chemicals from the plating baths. The quantities removed in the rinse tanks following plating are fed continuously to the waste treatment system in the appropriate waste streams, i.e., nickel bath constituents to acid-alkali stream, copper cyanide bath constituents to the cyanide stream, etc. The calculations that follow give the losses of each bath constituent as illustrated:

Copper cyanide bath, Line 1, make-up concentration

Copper cyanide, CuCN = 5.0 oz/gal
Sodium cyanide, NaCN = 7.0 oz/gal
Sodium hydroxide, NaOH = 0.5 oz/gal
Sodium carbonate, Na_2CO_3 = 2.0 oz/gal.

The hourly loss by drag out of copper cyanide (CuCN) is then

[Bath concentration, oz/gal] x [7.5] x [Drag out, l/day]

= (5.0 oz/gal)(7.5)(68.5 l/day)

= 2569 g/day = 2.569 kg/day = 5.671 lb/day of copper cyanide

where 7.5 is the factor converting oz/gal to g/l:

$$\frac{1\text{ oz}}{1\text{ gal}} \times 28.35\,\frac{\text{g}}{\text{oz}} \times \frac{1\text{ gal}}{3.785\text{ l}} = 7.5\,\frac{\text{g}}{\text{l}}$$

The quantity of the other copper bath constituents dragged out and going to the same waste treatment stream is:

NaCN: (7.0)(7.5)(68.5) = 3597 g/day = 3.597 kg/day = 7.939 lb/day

NaOH: (0.5)(7.5)(68.5) = 257 g/day = 0.257 kg/day = 0.567 lb/day

Na_2CO_3: (2.0)(7.5)(68.5) = 1028 g/day = 1.028 kg/day = 2.268 lb/day

The calculated losses for the nickel plating bath are :

$NiSO_4 \cdot 6H_2O$: (40)(7.5)(68.5) = 20550 g/day = 20.55 kg/day
= 45.36 lb/day

$NiCl_2 \cdot 6H_2O$: (6.0)(7.5)(68.5) = 3083 g/day = 3.083 kg/day
= 6.805 lb/day

H_3BO_3: (5.0)(7.5)(68.5) = 2569 g/day = 2.569 kg/day = 5.671 lb/day

Most nickel plating installations would consist of a semibright nickel bath followed by a bright plating bath with a direct transfer from the first to the second bath without rinsing. Consequently, the single drag out loss calculated suffices. Organic additives contained in the waste have been omitted from the calculations because their low concentrations are not captured in the precipitates of the waste treatment system unless a carbon filter is used to polish the final plant effluent.

Drag out losses from the electroless nickel rinse of Line 9 are 5.2 gal/day or 19.7 l/day for a total nickel concentration of

6.3 g/l* x 19.7 l/day = 124 g/day = 0.272 lb/day.

The rinse stream of 230 gal/day (871 l/day) is treated separately from the acid-alkali rinses, since a higher pH of 13.0 is required to destroy the nickel complex. The wastes that occur from the regeneration of the electroless nickel bath are discussed later in the section on bath maintenance.

The losses from the chromium plating bath by drag out are

CrO_3: (45)(7.5)(68.5) = 23,119 g/day = 23.119 kg/day = 51.04 lb/day

H_2SO_4: (0.45)(7.5)(68.5) = 231.2 g/day = 0.231 kg/day = 0.51 lb/day.

Cyanide-containing solutions are carried off to the treatment plant in a separate stream for destruction of the cyanide, requiring a calculation for the total cyanide in the raw wastes from the plant to determine the quantity of treatment chemicals needed and the quantity of waste produced. In the case of the copper plating bath of Line 1, for example, the quantity of cyanide present in the rinse stream is calculated as before times a factor describing the fraction of CN present in each salt

from CuCN: (5.0)(7.5)(68.5)(0.291) = 747.5 g/day = 1.65 lb/day of cyanide

from NaCN: (7.0)(7.5)(68.5)(0.531) = 1907 g/day = 4.22 lb/day of cyanide.

Factors for other cyanide-containing chemicals are not needed in the calculations because metal content rather than metal cyanide content is given in the description of other plating baths in Table B-2. The metal content of the respective cyanide salt is calculated just as above with the multiplying factor relating the metal portion of the salt as shown for copper of Line 1

from CuCN: (5.0)(7.5)(68.5)(0.71) = 1824 g/day = 4.03 lb/day of copper.

Applying the above procedures for calculating metal ion content and anion content (CN, SO_4, etc.) for each of the plating baths yields the total amount of materials that must be reacted in the waste treatment system. The respective amounts are shown in Tables B-4 through B-6.

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* $NiSO_4 \cdot 7H_2O$ Concentration = 30 g/l = 6.3 g/l Ni.

Cyanide Destruction

The destruction of cyanide will be carried out using chlorine (Cl_2) and caustic soda (NaOH) at a pH of about 9 to 10. The theoretical quantity of chlorine required is 3.62 lb per pound of sodium cyanide or 6.82 lb per pound of cyanide according to the following equation:

$$2\ NaCN + 5\ Cl_2 + 12\ NaOH \longrightarrow Na_2CO_3 + 10\ NaCl + N_2 + 6\ H_2O.$$

Allowing 10 percent excess Cl_2, 7.50 lb or 3.40 kg Cl_2 per lb or kg CN is required. For a total CN-content of 31.95 lb/day the amount of chlorine required is:

$$31.95\ \frac{\text{lb CN}}{\text{day}} \times \frac{7.5\ \text{lb } Cl_2}{1\ \text{lb CN}} = 239.6\ \frac{\text{lb } Cl_2}{\text{day}} \text{ or } 108.6\ \frac{\text{kg } Cl_2}{\text{day}}\ .$$

From the same equation, and again allowing for a 10 percent excess, 326 lb of NaOH will be required per hour to destroy the cyanide. If used as a 50 weight percent solution, which contains 6.36 lb/gal NaOH, the volume required is:

$$\frac{326\ \text{lb/hr}}{6.36\ \text{lb/gal}} = 51.2\ \text{gal/day or } 193.8\ \text{l/day.}$$

It is also possible to carry out the cyanide destruction process using lime instead of caustic. The theoretical ratio of lime [$Ca(OH)_2$] to caustic (NaOH) required for neutralization is:

$$\frac{Ca(OH)_2}{2NaOH} = \frac{74.10}{2(40.01)} = 0.926\ .$$

The quantity of lime required is:

$$326 \times 0.926 = 301.9\ \text{lb/day of } Ca(OH)_2\ .$$

The same results would be obtained if one were to substitute 12 NaOH for 6 $Ca(OH)_2$ in the above equation.

Chromium Reduction

The reduction of hexavalent chromium to trivalent chromium in the waste stream will be carried out using sulfur dioxide (SO_2) gas at a solution pH from 2.5 to 3.0. From the equation,

$$2\ CrO_3 + 3\ SO_2 \longrightarrow Cr_2(SO_4)_3$$

the theoretical quantity of SO_2 required per pound or kg of CrO_3 is 0.961 lb or 0.435 kg. With a chromium content of 52 percent in CrO_3, the amount of SO_2 required is $\frac{0.961}{0.52}$ = 1.85 lb or 0.84 kg per lb or kg of Cr. The use of 2.1 lb or 0.92 kg SO_2 is required when the gas is fed in excess of 10 percent.

Using the example of the chromium plating bath of Line 1, as given in Table B-2, the drag out loss is 23.06 kg/day = 50.9 lb/day of CrO_3, which, when multiplied by 0.52, gives 11.99 kg/day or 26.47 lb/day of hexavalent chromium in the waste stream requiring

$$11.99 \times 0.84 = 10.07 \text{ kg/day or } 22.23 \text{ lb/day of } SO_2.$$

Equivalent calculations were carried out for the chromium baths of Lines 2 and 6 and the CrO_3 hot dip step in Line 8. The chromium lost from the chromating steps following zinc and cadmium deposition has been included in the drag out and dump calculations presented in Appendix A-2, Lines 3, 4, and 5. These rinse and dump solutions also contain dissolved electrodeposited zinc or cadmium. These quantities are calculated from the combined daily dump and rinse volumes times the metal ion concentration dissolved in solution by 1/2 of the nitric acid concentration. Total Cr^{+6} from the seven lines including dumps is as follows:

$$25.54 + 7.57 + 3.81 + 1.088 + 0.872 + 0.432 + 0.027 = 39.34 \text{ lb/day}$$
$$= 17.82 \text{ kg/day.}$$

The total flow of streams is as follows:

$$3900 + 1100 + 560 + 930 + 920 + 320 + 50 = 7780 \text{ gal/day} = 29{,}450 \text{ l/day.}$$

The average Cr^{+6} concentration of the combined streams and dumps equals

$$\frac{17{,}820{,}000 \text{ mg/day}}{29{,}450 \text{ l/day}} = 605 \text{ mg/l .}$$

In addition to the Cr^{+6} these streams also carry

$$Zn = 0.648 + 0.520 = 1.17 \text{ lb/day} = 0.53 \text{ kg/day}$$

$$Cd = 0.56 \text{ lb/day} = 0.253 \text{ kg/day.}$$

It will be assumed that the pH of the combined chromium-stream will be at a pH of 2.5-3.0 at which the reduction of Cr^{+6} will be carried out by the addition of sulfur dioxide. For the above calculated totals,

$$39.34 \text{ lb/day} \times 2.1 \frac{\text{lb } SO_2}{\text{lb Cr}} = 82.6 \text{ lb/day} = 39.42 \text{ kg/day}$$

of sulfur dioxide are required.

Acid-Alkali Stream

The quantity of the various materials going to the waste treatment plant from the combined acid-alkali and nickel rinse streams and the dumps from Lines 1 to 9 together with the Al-anodizing and Zn-phosphating line processing solution rinses and dumps are summarized in Table B-4. The total quantity of individual materials present in the combined lines is given at the right of Table B-4.

Acid-Alkali Stream Neutralization. The determination of the quantity of caustic soda or lime that will be required to react with the excess acid present in the stream was carried out as follows:

(1) The various acids and alkalis were reacted together until all the alkali was used up.

(2) The excess acid present was then neutralized using either caustic soda or lime.

The sequence of reacting the various acid and alkaline materials present in the overall acid-alkali stream (Table B-4) and the attendant calculations are shown below:

(1a) Neutralization of HNO_3 with Na_2CO_3:

HNO_3 present = 34.28 lb/day = 15.54 kg/day

Na_2CO_3 present = 40.76 lb/day = 18.57 kg/day

The amount of Na_2CO_3 used up is then 34.28 $\frac{\text{lb}}{\text{day}}$ x 0.84 = 28.80 lb/day = 13.04 kg/day, where 0.84 is the molecular weight ratio of the acid-alkali neutralization reaction. The amount of Na_2CO_3 left unreacted is then 40.76 lb/day - 28.80 lb/day = 11.96 lb/day = 5.42 kg/day.

(1b) Neutralization of HCl with Na_2CO_3 and NaOH:

NaOH present = 81.60 lb/day = 36.91 kg/day

Na_2CO_3 left from (1a) = 11.96 lb/day = 5.42 kg/day

11.96 lb Na_2CO_3 will neutralize 8.26 lb HCl

HCl left = 65.99 - 8.26 = 57.73 lb/day = 26.15 kg/day.

The amount of NaOH required to neutralize this amount of HCl is

57.73 lb/day x 1.10 = 63.50 lb/day or 28.77 kg/day

and the amount of NaOH left unreacted is

81.60 - 63.50 = 18.10 lb/day = 8.20 kg/day.

(1c) Neutralization of H_3BO_3 with NaOH:

H_3BO_3 present = 7.29 lb/day = 3.30 kg/day

NaOH left from (1b) = 18.10 lb/day = 8.20 kg/day

NaOH required to react with 7.29 H_3BO_3 is

7.29 lb/day x 0.65 = 4.74 lb/day = 2.15 kg/day

TABLE B-4. MATERIALS GOING TO WASTE TREATMENT PLANT FROM COMBINED ACID-ALKALI AND NICKEL STREAM RINSES AND DUMPS

Item	Line 1 kg/day	Line 2 kg/day	Line 3 kg/day	Line 4 kg/day	Line 5 kg/day	Line 6 kg/day	Line 7 kg/day	Line 8 kg/day	Line 9 kg/day	Combined Lines kg/day
NaOH	4.72+3.92	1.43+0.89	2.83+1.42	3.57+1.13	3.40+2.27	0.85	8.55	0.74	1.19	36.91
Na_2CO_3	3.04+1.52	0.90+0.33	2.27	2.24	2.72	0.68	3.62	0.47	0.78	18.57
Na_2SiO_3	3.44+4.56	1.02+1.02	0.23	2.55	0.27	0.07	4.08	0.53	0.85	18.62
$Na_3PO_4 \cdot 12H_2O$	1.76+1.12	0.49+0.25	0.29	1.33	0.34	0.09	0.91	0.25	0.41	7.24
H_2SO_4	9.86+20.25	3.64+8.10	-	-	-	9.67	56.47	-	-	107.99
H_3BO_3	2.57	0.73	-	-	-	-	-	-	-	3.30
HCl	-	-	3.36	4.48	6.71	-	-	5.67	9.67	29.89
HNO_3	-	-	-	7.71	-	-	7.18+0.65	-	-	15.54
H_3PO_4	-	-	-	-	-	-	14.44	1.056	-	15.496
Fe	0.692	0.255	0.643	0.856	1.29	1.37	-	1.085	1.852	8.043
Cu	0.239	0.088	-	-	-	-	0.344	-	-	0.671
Zn	0.224	0.038	-	-	-	-	-	0.535	-	0.797
Al	-	-	-	-	-	-	1.444+6.804 + 0.323	-	-	8.567
Mn	-	-	-	-	-	-	0.196	-	-	0.196
Ni	4.58+0.69	1.502	-	-	-	-	0.357	-	0.130	7.259

TABLE B-4. (Continued)

Item	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	lb/day	Combined Lines lb/day
NaOH	10.48 + 8.72	3.15 + 1.97	6.25 + 3.12	7.88 + 2.50	7.50 + 5.01	1.884	18.87	1.64	2.63	81.60
Na_2CO_3	6.64 + 3.28	1.98 + 0.73	5.00	4.95	6.00	1.50	8.00	1.03	1.65	40.76
Na_2SiO_3	7.52 + 10.0	2.25 + 2.25	0.50	5.63	0.60	0.15	9.00	1.17	1.88	40.95
$Na_3PO_4 \cdot 12H_2O$	3.92 + 2.48	1.08 + 0.55	0.63	2.93	0.75	0.19	2.00	0.56	0.90	15.99
H_2SO_4	21.76 + 44.70	8.04 + 17.88	-	-	-	21.34	124.70	-	-	238.40
H_3BO_3	5.67	1.62	-	-	-	-	-	-	-	7.29
HCl	-	-	7.41	9.88	14.82	-	-	12.52	21.36	65.99
HNO_3	-	-	-	17.02	-	-	15.85 + 1.41	-	-	34.28
H_3PO_4	-	-	-	-	-	-	31.87	0.59	-	32.46
Fe	1.53	0.564	1.42	1.89	2.84	3.03	-	2.40	4.09	17.76
Cu	0.528	0.194	-	-	-	-	0.76	-	-	1.48
Zn	0.224	0.084	-	-	-	-	-	1.18	-	1.49
Al	-	-	-	-	-	-	3.19 + 15.02 + 0.32	-	-	18.53
Mn	-	-	-	-	-	-	0.43	-	-	0.43
Ni	11.64	3.52	-	-	-	-	0.788	-	0.27	16.22

and the amount of NaOH left unreacted is

18.10 - 4.74 = 13.36 lb/day = 6.05 kg/day.

(1d) Neutralization of H_3PO_4 with NaOH:

H_3PO_4 present = 32.46 lb/day = 15.50 kg/day

The amount of NaOH required to react with this amount of H_3PO_4 is

32.46 lb/day x 1.22 = 39.60 lb/day = 17.94 kg/day.

(2a) Since only 13.36 lb NaOH are available in the waste stream, the addition of 39.60 - 13.36 = 26.24 lb/day = 11.89 kg/day of NaOH is required.

(2b) Neutralization of H_2SO_4 with NaOH:

H_2SO_4 present = 238.4 lb/day = 107.99 kg/day

The amount of NaOH required to react with this amount of acid is

238.4 lb/day x 0.82 = 195.5 lb/day = 88.56 kg/day.

Allowing for a NaOH feed rate 10 percent in excess of the theoretical amount

1.10 x 195.5 lb/day = 215.1 lb/day = 97.42 kg/day are required.

Combining (2a) and (2b), 241.3 lb/day (109.3 kg/day) of additional NaOH is needed for the overall neutralization of the acid-alkali stream. The equivalent amounts of $Ca(OH)_2$ that would be required in lieu of NaOH would be

241.3 lb/day x 0.926 = 223.4 lb/day = 101.2 kg/day.

The final pH of the acid-alkali stream, excluding precipitation of any metal hydroxides, is assumed to be 6.0.

Caustic or Lime Requirements for Raising pH of Solutions. It will be assumed that when the treated cyanide stream (8380 gal/day or 31,720 l/day, pH 9 to 10) is joined with the treated chromium stream (7780 gal/day or 29,450 l/day, pH 2.5 to 3.0) that the resultant pH of the stream will be at 5.0. It will also be assumed that the pH of all the streams making up the overall acid/alkali stream (62,680 gal/day = 237,240 l/day) after neutralization of the free acid contents with either NaOH or lime will be 6.0.

To raise the pH of the combined CN and Cr streams from 5.0 to 8.5 requires $10^{-5.5}$ moles/liter of NaOH (M wt = 40)

$$\approx 10^{-5.5} \text{ M/l} \times 40 \text{ g/M} = 4 \times 10^{-4} = 0.0004 \text{ g/l of NaOH}$$

and the total amount of NaOH needed is

$$4 \times 10^{-4} \text{ g/l} \times (31{,}720 + 29{,}450) \text{ l/day} = 24.47 \text{ g/day.}$$

Feeding NaOH to 10 percent in excess of the calculated amount would then require 24.47 x 1.10 = 26.92 g/day.

To raise the pH of the acid-alkali stream from 6.0 to 8.5 also requires $10^{-5.5}$ moles/liter of NaOH. For a total flow rate of 237,240 l/day and allowing a NaOH feed 10 percent in excess of the theoretical amount, the required amount of NaOH is

$$4 \times 10^{-4} \text{ g/l} \times 237{,}240 \text{ l/day} \times 1.10 = 104.4 \text{ g/day}.$$

The total amount NaOH is then 24.47 + 104.4 = 129 g/day or 0.28 lb/day. The equivalent amount of $Ca(OH)_2$ is 129 x 0.926 = 120 g/day or 0.26 lb/day.

Combined Flow Stream Calculations. The following are the flows for the main streams in the overall waste-treatment (WT) plant:

Combined cyanide streams	8380 gal/day or 31,720 l/day
Combined chromium streams	7780 gal/day or 29,450 l/day
Combined A-A streams (including Ni rinses and dumps, anodizers, and phosphating rinses and dumps, etc.)	62,680 gal/day or 237,240 l/day
Electroless Ni rinses (to clarifier)	230 gal/day or 870 l/day
Total Volume	79,070 gal/day or 299,280 l/day.

By including an additional 5 percent volume of water used in water treatment, processing chemicals, wash down, etc., the total plant effluent flow becomes 83,100 gal/day or 314,500 l/day.

Quantity of NaOH Required to Precipitate Metal Ions as Hydroxides. The use of the metal contents calculated for the various waste streams (Table B-6) when multiplied by the equivalent quantity of NaOH gives the quantity of metal hydroxides precipitated as dry weight of sludge. For example, the chromium waste stream carries 39.34 lb/day or 17.82 kg/day of hexavalent chromium, Cr^{6+}, which has been reduced to trivalent chromium, Cr^{3+}, which is then precipitated according to the equation

$$Cr^{3+} + 3OH^{-} \rightarrow Cr(OH)_3$$

requiring 3 moles of NaOH for each mole of Cr^{3+}, or 52.01 g Cr react with 120.00 g NaOH to form 103.01 g $Cr(OH)_3$.

Consequently,

$$\frac{120.00 \text{ g} \times 17{,}820 \text{ g/day}}{52.01 \text{ g}} = 41{,}115 \text{ g/day}$$

of NaOH is required, forming

$$\frac{103.01 \text{ g}}{52.01 \text{ g}} \times 17{,}820 \text{ g/day} = 35{,}294 \text{ g/day}$$

of $Cr(OH)_3$. Expressed as lb/hr, the respective amounts are 90.76 and 77.91.

Similarly, the 1.17 lb/day (0.53 kg/day) of Zn^{2+} require 1.40 lb/day (0.64 kg/day) of NaOH to produce 1.69 lb/day (0.76 kg/day) of $Zn(OH)_2$, and 56 lb/day (0.25 kg/day) of Cd^{2+} require 0.40 lb/day (0.18 kg/day) of NaOH to produce 0.72 lb/day (0.33 kg/day) of $Cd(OH)_2$.

The quantities of all the metal hydroxides from the cyanide and acid-alkali stream were calculated in likewise fashion.

Quantity of $Ca(OH)_2$ Required to Precipitate Metal Ions as Hydroxides. The theoretical ratio of lime to caustic soda is 0.926 (p. B-24). The quantity of metal-ion concentrations in the waste streams and the quantity of precipitated metal hydroxides are unchanged from those calculated with the use of NaOH. From the preceding paragraph, 41,115 g/day (90.76 lb/day) of NaOH is required to precipitate all chromium in the waste. Using $Ca(OH)_2$, instead, would then require 41,115 g/day x 0.926 = 38,073 g/day = 84.05 lb/day.

Total quantities of metal hydroxides formed for each metal ion in solution are summarized in Table B-5.

Determination of Solubility of $CaSO_4$ Formed During the Precipitation of the Metal Hydroxides with $Ca(OH)_2$. The solubility of $CaSO_4$ in water at 20 C (68 F) is 2.980 g/l. Therefore, the maximum amount of dissolved $CaSO_4$ that could leave the plant in the treated effluent is

$$\frac{314{,}500\ \text{l/day} \times 2.980\ \text{g/l}}{1000\ \text{g/kg}} = 937\ \text{kg/day} = 2069\ \text{lb/day}.$$

The quantity of $CaSO_4$ formed by the neutralization of 107.99 kg/day (238.4 lb/day) of H_2SO_4 in the waste stream, requiring 74.1 g $Ca(OH)_2$ for each 98 g of H_2SO_4 to produce 136.2 g of $CaSO_4$, is

$$107.99\ \text{kg/day} \times 1.39 = 150.1\ \text{kg/day} = 331.4\ \text{lb/day}$$

using

$$107.99\ \text{kg/day} \times 0.75 = 81.0\ \text{kg/day} = 178.8\ \text{lb/day}$$

plus 10 percent excess for a total of 89.1 kg/hr = 196.7 lb/day of $Ca(OH)_2$.

Making the assumption that the incoming plant water contains 100 mg/l of Ca in the form of $CaSO_4$ the additional quantity of Ca is

$$\frac{314{,}500\ \text{l/day} \times 0.100\ \text{g/l}}{1000\ \text{g/kg}} = 31.45\ \text{kg/day} = 69.43\ \text{lb/day}$$

or, the quantity of $CaSO_4$ added is

$$31.45\ \text{kg/day} \times 3.40 = 106.9\ \text{kg/day} = 236.0\ \text{lb/day}.$$

The total quantity of $CaSO_4$ in the stream is then 150.1 + 106.9 = 257.0 kg/day = 567.3 lb/day, which amounts to 60 percent of the calculated solubility. Therefore, no solid waste is generated.

TABLE B-5. METAL HYDROXIDES LEAVING AS WASTES

Hydroxide	Total Quantity in Combined Streams kg/day	Total Quantity in Combined Streams lb/day	Correction for Metal Values Leaving in Effluent kg/day	Correction for Metal Values Leaving in Effluent lb/day	Corrected Value of Hydroxides Leaving with Wastes kg/day	Corrected Value of Hydroxides Leaving with Wastes lb/day
$Al(OH)_3$	24.77	54.68	0.92	2.01	23.85	52.67
$Cu(OH)_2$	4.62	10.20	0.24	0.53	4.38	9.67
$Cd(OH)_2$	1.17	2.58	0.21	0.45	0.96	2.13
$Cr(OH)_3$	35.29	77.91	0.31	0.69	34.98	77.22
$Fe(OH)_2$	15.38	33.95	0.60	1.33	14.78	32.62
$Ni(OH)_2$	11.47	25.32	0.25	0.55	11.22	24.77
$Zn(OH)_2$	13.84	30.55	0.24	0.53	13.60	30.02
$Mn(OH)_2$	0.32	0.71	0.25	0.56	0.07	0.15
Total	--	--	--	--	103.84	229.25

Determination of Solubility of Ca_3PO_4 and $CaSiO_3$ Formed During The Precipitation of the Metal Hydroxides with $Ca(OH)_2$. With the lime precipitation option employed at the final neutralization/precipitation step, calculations were made to determine whether the quantity of sodium silicate and sodium phosphate originally leaving as soluble sodium salts (with complete NaOH neutralization/precipitation) might be converted to relatively insoluble calcium silicate and calcium phosphate salts, respectively, which would leave in the solid waste sludge. The quantity of Na_2SiO_3 and $Na_3PO_4 \cdot 12H_2O$ going to the waste treatment system from the cleaners is as follows (Table B-4):

Na_2SiO_3: 18.62 kg/day = 40.95 lb/day

$Na_3PO_4 \cdot 12H_2O$: 7.24 kg/day = 15.99 lb/day.

The quantity of calcium salts used with lime instead of caustic soda are

$$CaSiO_3 = Na_2SiO_3 \times 0.95 = 18.62 \times 0.95 = 17.69 \text{ kg/day} = 39.05 \text{ lb/day}$$

$$Ca_3(PO_4)_2 = Na_3PO_4 \cdot 12H_2O \times 0.41 = 7.24 \times 0.41 = 2.97 \text{ kg/day} = 6.55 \text{ lb/day.}$$

The solubilities of the calcium salts are

$CaSiO_3$ = 0.095 g/l at 17 C

$Ca_3(PO_4)_2$ = 0.020 g/l in cold water.

The quantity of dissolved salts that could be discharged with the plant effluent are

$$CaSiO_3: \frac{314,500 \text{ l/day} \times 0.095 \text{ g/l}}{1000 \text{ g/kg}} = 29.88 \text{ kg/day} = 65.95 \text{ lb/day}$$

and

$$Ca_3(PO_4)_2: \frac{314,500 \text{ l/day} \times 0.02 \text{ g/l}}{1000 \text{ g/kg}} = 6.29 \text{ kg/day} = 13.87 \text{ lb/day.}$$

Since the quantity formed is less than the soluble amounts that could be carried out in the liquid effluent stream, there will be essentially no $Ca_3(PO_4)_2$ and $CaSiO_3$ leaving with the solid wastes.

Table B-6 gives the metal concentrations present in each waste treatment stream and the quantity of the respective metal hydroxides formed as well as the quantity of the reagents required. In the case of the cyanide stream, the quantity of NaOH or $Ca(OH)_2$ that is required is that which was calculated earlier as needed for the destruction of the cyanide stream and the simultaneous precipitation of the metal hydroxides.

TABLE B-6. METAL ION CONCENTRATIONS IN WASTE STREAMS, QUANTITY OF METAL HYDROXIDE SLUDGE FORMED AND REAGENTS USED FOR PRECIPITATION

	Concentration		Quantity of $Me_x(OH)_y$ Formed		Quantity of Reagents Required*			
					NaOH		$Ca(OH)_2$	
Me Ion	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
A. Cyanide Stream								
Cu^{2+}	2.34	5.18	3.59	7.93	2.95	6.50	2.73	6.03
Zn^{2+}	7.80	17.22	11.86	26.17	9.55	21.08	8.84	19.52
Cd^{2+}	0.65	1.43	0.84	1.87	0.46	1.02	0.43	0.94
Subtotal	10.79	23.83	16.29	35.97	12.96	28.60	12.00	26.49
B. Chromium Stream								
Cr^{3+}	17.82	39.34	35.29	77.91	41.12	90.76	38.08	84.06
Zn^{2+}	0.53	1.17	0.76	1.69	0.64	1.40	0.59	1.31
Cd^{2+}	0.25	0.56	0.33	0.72	0.18	0.40	0.17	0.37
Subtotal	18.60	41.07	36.38	80.32	41.94	92.56	38.84	85.73
C. Acid-Alkali Stream								
Cu^{2+}	0.67	1.48	1.03	2.27	0.84	1.86	0.78	1.71
Zn^{2+}	0.80	1.49	1.22	2.68	0.98	2.16	0.91	2.00
Fe^{3+}	8.04	17.76	15.38	33.95	17.27	38.13	15.99	35.30
Ni^{2+}	7.13	15.95	11.26	24.86	9.72	21.45	9.00	19.87
Mn^{2+}	0.20	0.43	0.32	0.71	0.29	0.64	0.27	0.59
Al^{3+}	8.57	18.53	24.77	54.68	38.12	84.14	35.30	77.92
Subtotal	25.41	55.64	53.98	119.51	67.22	148.38	62.25	137.39
D. Electroless Ni-Stream								
Ni^{++}	0.13	0.27	0.21	0.45	0.37	0.81	0.34	0.76

*Includes 10 percent in excess of theoretical amounts.

The quantity of metal hydroxides formed from the various streams was calculated on the basis of a complete conversion of the metal to the hydroxide. To determine the quantity of hydroxides that would wind up with the solid waste sludge, it is necessary to make an allowance for the metal values leaving in the effluent stream either as the dissolved metal or in the suspended solids. To make this correction, the following concentrations of metals (either dissolved or in the suspended solids) in the effluent were assumed.

Metal	Concentration, mg/l
Copper	0.5
Nickel	0.5
Chromium	0.5
Zinc	0.5
Aluminum	1.0
Cadmium	0.5
Iron	1.0
Manganese	0.5

Multiplying the volume of effluent by the above concentration gives the total amount of metal ions leaving in the plant effluent either as dissolved solids or suspended metal hydroxides. For a concentration of metal in the effluent of 0.5 mg/l the total metal is

$$0.5 \times 10^{-6} \text{ kg/l} \times 314{,}500 \text{ l/day} = 0.1573 \text{ kg/day} = 0.347 \text{ lb/day}$$

and twice as much for the concentration of 1.0 mg/l. Converting the metal concentrations to their respective hydroxides and subtracting this amount from the total hydroxides precipitated gives the quantity of metal hydroxides discharged from the waste treatment plant for land disposal.

Clarifier Calculations

The following calculations were carried out to determine the flocculent dosage, sludge volume, etc.:

(1) The total quantity of metallic hydroxides (excluding $Ca(OH)_2$ present is 103.8 kg/day or 229.3 lb/day. The quantity of insoluble sludges occurring from the cleaners is 23.6 kg/day or 52.1 lb/day. The quantity of unreacted $Ca(OH)_2$ (based on 70 percent of the 10 percent excess lime used for neutralization/precipitation operations) is 33.92 x 0.7 = 23.74 kg/day or 52.42 lb/day.

(2) A flocculent will be employed in the clarifier, so that the effluent from the top of the clarifier would be suitable for discharge to a stream (or sewer) [e.g., 10-20 ppm suspended solids]. The flocculent is generally fed as a dispersion (about 5 percent) to the neutralized waste at a dosage of

10 to 100 mg/l. For the model plant a value of 40 mg/l will be employed. The quantity of flocculent required is as follows:

$$314{,}500 \text{ l/day} \times 40 \times 10^{-6} \text{ kg/l} = 12.58 \text{ kg/day}$$

or 27.77 lb/day.

The total amount of solids is then 103.8 + 23.64 + 12.58 = 139.98 kg/day = 309.0 lb/day when NaOH is used, and with the use of lime, is 139.98 + 23.74 = 163.72 kg/day = 360.9 lb/day.

It will be assumed that the clarifier will produce an underflow containing 2 percent solids. It will also be assumed that the density of the 2 percent sludge mixture will be similar to that of water. The volume of underflow is calculated to be

$$\frac{139.98 \text{ kg/day}}{0.02 \times 1.00 \text{ kg/l}} = 7000 \text{ l/day} = 1849 \text{ gal/day}$$

using NaOH for the process, and similarly 8186 l/day or 2163 gal/day using $Ca(OH)_2$.

The alternate use of a sludge thickener (centrifuge) will be assumed to concentrate the sludge from 2 to 20 percent solids producing a sludge cake of 801 l/day (185 gal/day) or 819 l/day (217 gal/day) when NaOH or $Ca(OH)_2$ is used in the treatment process. The higher volume of sludge with the lime neutralization/precipitation system results from the fact that some of the unreacted $Ca(OH)_2$ leaves with the sludge destined for waste disposal.

Summarized Data on Chemicals Consumption in Waste Treatment Plant

The caustic or lime consumption in the waste treatment plant (based on 10 percent in excess of theoretical requirement) is summarized in Table B-7. The consumption of chlorine, sulfuric dioxide, and flocculent in the waste treatment plant were as follows:

	kg/day	lb/day
Chlorine:	108.6	239.7
Sulfur dioxide:	30.42	82.6
Flocculent:	12.58	27.8

TABLE B-7. CAUSTIC SODA OR LIME CONSUMPTION IN WASTE TREATMENT OPERATIONS

Operation	NaOH		$Ca(OH)_2$	
	kg/day	lb/day	kg/day	lb/day
CN-destruction	148	326	137	302
Chromium-stream metal precipitation	41.9	92.6	38.8	85.7
Neutralization of acids in A-A stream	109	241	101	223
Raising pH of A-A stream from 6.0 to 8.5	0.10	0.20	0.10	0.20
Raising pH of combined CN and Cr stream from 5.0 to 8.5	0.03	0.06	0.03	0.06
A-A stream metal precipitation	67.2	148	62.3	137
Total consumption	366.2	807.9	339.2	748.0

Materials Consumption in Model Plant

Anode Consumption

The quantity of soluble anodes used for each electroplating operation will closely approximate the quantity of metals plated out. Making assumptions for plate thickness and using the numbers of processed area for each operation, the anode use is calculated from a modified form of Faraday's Law commonly used by platers and given in most plating handbooks:

$$\text{Wt in lbs deposited} = \frac{\text{area plated x plate thickness x unit wt/unit thickness}}{\text{16 oz/lb}}.$$

For example, the quantity of copper deposited when 7,747 sq ft (720 m^2) are plated per day to a thickness of 0.000075 inch (0.075 mil) or 0.19 μm is

$$\text{Wt of Cu} = \frac{\text{7,747 sq ft/day x 0.075 mil x 0.74 oz/sq ft mil}}{\text{16 oz/lb}} = \text{26.87 lb/day}$$
$$= \text{12.17 kg/day.}$$

The following is the summarized data on the anode consumption for the model plant. Anode wastes are discussed in Section B of this phase of the report.

Anode Metal	Factor oz/sq ft mil	Deposit Thickness mil		Anode Consumption kg/day	
		mil	μm	kg/day	lb/day
Copper	0.74	0.075	0.19	12.17	26.87
Nickel	0.742	0.6	15.2	97.20	214.57
Zinc	0.59	0.32	8.13	73.36	161.94
Cadmium	0.72	0.35	8.89	12.32	27.20

Bright Dip Consumption (Line 7)

Using the assumption that 85 percent of the bright dip solution is recovered by use of three stagnant rinses following the bright dip operation, the spent bright dip solution is periodically withdrawn from the first tank as a solution containing about 35 percent H_3PO_4 acid and sold to a fertilizer manufacturer.

This drag out would account for the consumption of 15 percent of the bright dip solution (which initially has a concentration of 67 percent H_3PO_4 - 3 percent HNO_3.) From earlier calculations

the quantity of H_3PO_4 carried off in the drag out = 14.44 kg/day
= 31.87 lb/day

the quantity of HNO_3 carried off in the drag out = 0.65 kg/day
= 1.43 lb/day.

Since these values represent 15 percent of the consumption of the original bright dip solution, the amount of bright dip ingredients needed is as follows:

$$H_3PO_4: \frac{14.44}{0.15} = 96.25 \text{ kg/day} = 212.23 \text{ lb/day}$$

$$HNO_3: \frac{0.65}{0.15} = 4.31 \text{ kg/day} = 9.50 \text{ lb/day.}$$

The 85 percent of the spent bright dip solution (35 percent H_3PO_4) hauled away per day is equal to $\underline{81.81 \text{ kg or } 180.4 \text{ lb } H_3PO_4}$. The volume hauled away based on 35 percent H_3PO_4 which has a density of 1.436 g/cm^3 is

$$\frac{81.81 \text{ kg/day}}{1436 \text{ g/l}} \times 1000 \frac{\text{g}}{\text{kg}} \; 56.97 \text{ l/day} = 15.05 \text{ gal/day.}$$

The quantity of HNO_3 hauled away with the bright dip is 3.64 kg/day or 8.02 lb/day.

Summary of Materials Consumption

The materials consumed in the model plant in electroplating and metal finishing operations are summarized in Table B-8.

Sludge-Handling Operations

To provide data and information on the different sludge-handling and disposal procedures, calculations of costs for two disposal methods (designated Options 1 and 2 in Figure B-2) were carried out. Option 1 involves the use of a centrifuge on the underflow from the clarifier to concentrate the sludge from a 2 percent to a 20 percent solids content. Option 2 employs a lagoon to settle out and concentrate the sludge to a 6 percent solids content. The calculations for each option follow.

Option 1 - Centrifuged Sludge Disposal Calculations
Centrifuge Size and Cost Calculations

The earlier calculations had shown that the underflows from the clarifier (assuming a 2 percent solids content) were as follows:

(1) 7,000 l/day or 1,849 gal/day (caustic system)

(2) 8,186 l/day or 2,163 gal/day (lime system).

Conversion of the 2 percent solids underflow in a centrifuge to a sludge containing 20 percent solids resulted in the following volumes of sludge:

TABLE B-8. MATERIALS CONSUMPTION FOR MODEL PLANT ELECTROPLATING OPERATIONS

Material	Consumption kg/day	Consumption lb/day
Sodium hydroxide, $NaOH$(a)*	66.16	145.92
Sodium carbonate, Na_2CO_3(a)	28.88	63.68
Sodium metasilicate, Na_2SiO_3(a)	24.72	54.48
Trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$(a)	9.76	21.44
Surfactant(a)	4.08	8.96
Sodium cyanide, $NaCN$	25.28	55.68
Sodium dichromate, $Na_2Cr_2O_7 \cdot 2H_2O$	3.54	7.52
Nickel sulfate, $NiSO_4 \cdot 6H_2O$	26.72	58.88
Nickel sulfate, $NiSO_4 \cdot 7H_2O$	0.56	1.28
Nickel chloride, $NiCl_2 \cdot 6H_2O$	3.92	8.56
Nickel acetate, $NiC_2H_3O_2$	0.72	1.60
Phosphating salt, $H_3PO_4 \cdot Zn_3(PO_4)_2$	6.08	13.44
Sodium acetate, $NaC_2H_3O_2$	0.24	0.48
Sodium hypophosphate, $NaH_2PO_2 \cdot H_2O$	0.24	0.48
Chromic acid, CrO_3	37.92	83.60
Cadmium oxide, CdO	0.80	1.68
Zinc oxide, ZnO	4.80	10.64
Boric acid, H_3BO_3	3.20	7.12
Hydrochloric acid, HCl	27.68	61.04
Nitric acid, HNO_3	25.04	55.28(b)
Phosphoric acid, H_3PO_4	95.68	211.00(b)
Sulfuric acid, H_2SO_4	149.4	329.00

*Footnotes are listed on next page.

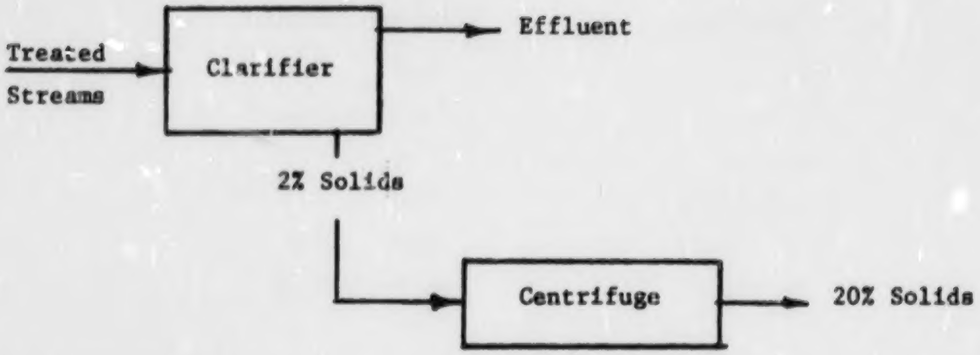
FOOTNOTES FOR TABLE B-8

(a) The bulk of these materials are contained in the soak and electrolytic cleaners used in the plant. The total quantity of cleaners used is 94.6 kg/day = 208.9 lb/day. The breakdown of the quantity of each compound used in the cleaners is given below:

Material	Consumption kg/day	Consumption lb/day
NaOH	31.6	69.8
Na_2CO_3	24.6	54.4
Na_2SiO_3	24.6	54.4
$Na_3PO_4 \cdot 12H_2O$	9.8	21.5
Surfactant	4.0	8.8
Total	94.6	208.9

(b) Part of the consumption shown for these two acids is employed for the bright dip operation on the Al anodizing line and is recovered and sold to a fertilizer manufacturer. The quantity of phosphoric and nitric acids recovered are 81.81 kg/day (180.4 lb/day) and 3.65 kg/day (8.02 lb/day), respectively.

OPTION 1



OPTION 2

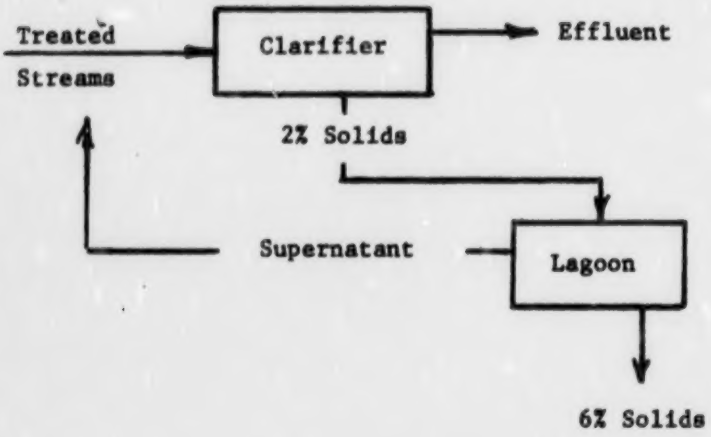


FIGURE B-2. SLUDGE-HANDLING OPTIONS

(1) 700 l/day or 185 gal/day (caustic system)

(2) 819 l/day or 217 gal/day (lime system).

The ratings of the centrifuges required were

(1) $\frac{7{,}000 \text{ l/day} \times 0.02}{0.06 \times 8 \text{ hr/day} \times 60 \text{ min/hr}}$ = 14.60 l/min or 3.86 gal/min caustic system)

(2) 17.01 l min or 4.51 gal/min (lime system).

Option 2 - Lagoon Sludge Disposal

For Option 2, it was assumed that the underflow from the clarifier was sent directly to a lagoon for further clarification and settling. It was also assumed that at the time the settled sludge was hauled away, the solids content had increased from 2 to 6 percent. The volume of 6 percent sludge to be hauled away was

(1) $\frac{7{,}000 \text{ l/hr} \times 0.02}{0.06}$ = 2,333 l/day or 617 gal/day (caustic system)

(2) $\frac{8{,}186 \text{ l/hr} \times 0.02}{0.06}$ = 2,729 l/day or 721 gal/day (lime system).

Lagoon Size. Since the lagoon size will not differ significantly for the two precipitation systems, the lagoon size calculations were based on the lime system. Assuming a holding capacity for 30 days (no discharge of supernatant liquid from the lagoon was assumed for these calculations) the size of the lagoon required was determined as follows:

Volume of underflow to lagoon: 8,186 l/day x 30 days = 245,580 l (245.6 m^3) or 64,883 gal (8,675 cu ft).

Allowing a 20 percent oversize, the volume required is 270.4 m^3 or 9,550 cu ft. Assuming a working depth of 2 m (6 ft), a length of 20 m (60 ft), and a width of 10 m (30 ft) and a 3 m (10 ft) wide border around the lagoon, therefore, requires a land area of 26 m x 16 m = 416 m^2 (80 ft x 50 ft = 4000 sq ft) or 0.092 acres.

(B) DETERMINATION OF THE QUANTITY OF WASTE GENERATED IN AN ELECTROPLATING AND METAL FINISHING PLANT FROM MECHANICAL PRE- AND POST-PLATING OPERATIONS, SOLUTION AND EQUIPMENT MAINTENANCE AND FROM ORGANIC SOLVENTS

Summary

In the section of this report entitled "Waste Characterization" numerous types of wastes were enumerated. The preceding discussion of the model plant deals strictly with the wastes generated from rinse waters and solution dumps which are disposed of principally as metal hydroxide sludges. The following section is an attempt to quantify all additional wastes which might occur, such as wastes from solution and equipment maintenance, as well as a number of add-on operations such as surface finishing both before and after plating.

The assumptions made for the model plant are incorporated in the following discussion. The operating conditions for the plant were further developed and are summarized in Table B-9. This exercise was necessary in order to arrive at reasonable quantities of waste. For example, filter cake volume, anode area and weight are dependent on the solution volume and the processing rate which, in turn, is dependent on the cathode current density and efficiency. The operational conditions used are those which are common in the industry and are given in metal finishing handbooks.

Some wastes were believed not to be significant. Failure of equipment and replacement of parts are such items. For instance, pumps require replacement of seals; piping, valves, spray nozzles, etc., need to be replaced occasionally; heat exchangers, heating or cooling coils, and tank linings have limited life, which is much greater than 1 year, however. Loss of hydraulic fluid from automated equipment, corroded duct work, and maintenance of heat and power supplies also are excluded, as well as replacement parts for the waste treatment system itself.

One can postulate many ways of how solutions and equipment can be maintained in terms of frequency and the type of equipment used, and what basis metal requires what specific kind of preplating preparation. Nevertheless, whatever operations are employed in a given plant, some wastes will result from it. While the model plant additions discussed here may not be typical, as there are many possible variations, the criteria set up are such that a plant could perform these operations, and, consequently, produce these types and quantities of waste which are summarized in Tables B-10 and B-11.

Wastes From Basis Metal Preparation

Some additional finishing of the basis metal was assumed to take place in the model plant. One half of the brass parts obtaining a decorative chromium finish (lines 1 and 2) require a high-luster finish. Cutting and polishing operations of 216 m^2/day (2,328 sq ft/day) were estimated to remove 3,040 kg/yr (6,710 lb/yr) of brass by abrasive action of polishing and buffing compounds and wheels on the parts, making the assumption that 6.35 µm (0.00025 inch) of metal was removed in the process. Similarly, if the compound was applied to a thickness of 0.0025 cm (0.001 inch), then 1.486 m^2 (16 sq ft) of area would use up 0.45 kg (1 lb) of compound assuming its density would be nearly equal to that of water. At such a rate, 12,607 kg (27,830 lb) of compound are consumed annually. Further waste is obtained from the wear of buffing and polishing wheels, taking it equal to the amount of brass removed, or 3,040 kg/yr (6,710 lb/yr). The combined wastes of 23,220 kg/yr (51,250 lb/yr) are precipitated in dry dust collectors and disposed of with regular trash to a landfill. The abrasive action causes the wheels and buffs to be worn down. At one-half of their original weight equal to 3,040 kg/yr (6,710 lb/yr) the unused portions are returned to the suppliers as waste for recycling. In order to perform these operations 12 men were added to the plant, assuming that all operations were performed manually. Alternatively, if the parts were the same, the operation could have been automated, reducing the required manpower and possibly the quantity of waste from control of compound and buff use.

As is the case with brass, it has been assumed that 50 percent of the steel parts processed in the automatic rack zinc line (line 3) required some form of basis metal preparation. Half of this quantity was assumed to go through a deburring operation and the remaining half through a burnishing operation. Assuming a basis metal thickness of 0.191 cm (0.075 inch), a total of 2,925 kg/day (6,456 lb/day) of steel parts must be deburred. For a deburring time of 2 hours, the load is distributed in 8 barrels containing 98 kg (200 lb) of parts. For a removal rate of 1/10 of 1 percent of the load, 1,510 kg/yr (3,330 lb/yr) of steel is removed using up an equal amount of aluminum oxide media, and 7,550 kg/yr (16,640 lb/yr) of proprietary compound, containing soaps, chelating and rust-preventative agents when the charge is 1 pound per load.

The burnishing operation is carried out with steel balls and shapes in the same number of barrels containing the same amount of proprietary compound, 7,550 kg/yr (16,440 lb/yr). No metal removal takes place; however, a replacement of 2 oz/load of steel media for wear and loss can be assumed, amounting to 2,080 lbs of steel per year. Whereas, most of the latter ends up with the general trash, the unloading of the charge by simply washing the parts with tap water occurs through the sewer, as is the case with the burnishing operation.

The preparation for hard chromium plating is accomplished by grinding the basis metal (steel). In this operation, 0.00125 cm (0.0005 inch) of steel is removed amounting to 7.95 kg/day (1.52 lb/day) or 2,060 kg/yr (4,550 lb/yr). It is also assumed that the parts are overplated with chromium by 0.00025 cm (0.001 inch) which must be removed by grinding. The quantity of chromium generated is 380 kg/yr (840 lb/yr), which can be collected and returned to a scrap dealer.

TABLE B-9. OPERATING CONDITIONS

Line No.	Bath	Bath Volume		Number of Stations	Coating Thickness		Cathode C.D.		Cathode Efficiency, percent	Cathode Area,	
		l	gal		μm	0.001 inch	A/dm^2	A/ft^2		dm^2	ft^2
1	Cu	3,800	1,000	1	2.0	0.075	2.5	25	50	372	40
	Ni	7,000	4,500	9	15	0.6	5.0	50	100	1616	174
	Cr	3,800	1,000	2	1.3	0.05	10	100	15	372	40
2	Cr	1,900	500	1	2.0	0.075	2.5	25	50	104	11.2
	Ni	5,700	1,500	3	15	0.6	5.0	50	100	455	49
	Cr	1,900	500	1	1.3	0.05	10	100	15	104	11.2
3	Zn	18,900	5,000	10	7.5	0.3	4.0	40	60	1719	185
4	Zn	11,400	3,000	6	7.5	0.3	4.0	40	60	1031	111
5	Cd	3,800	1,000	2	9.0	0.35	2.0	20	90	372	40
6	Cr	1,900	500	1	50	2	15	150	15	1003	108
7	Anodising	15,200	4,000	8	10	0.4	1.2	12	-	1486	160
8	Phosphating	2,300	600	3	10 mg/dm^2	0.003 oz/ft^2	-	-	-	5017	540
9	Electroless Ni	1,900	500	1	12.5	0.5	-	-	-	1997	215

FOR MODEL PLANT PLATING LINES

Anode Area		Avg. Anode Wt. in Bath		Anode Material	Anode Replacement Cycle, days	Filtering	Bath Purification	
dm^2	ft^2	kg	lb				Co_3 Removal	Electrolytic
557	60	739	1630	Rolled Bar	66	Continuous	X	
1616	174	2090	4610	Rolled depol.	28	Continuous		X
557	60	Insoluble		Pb-Sb	-	-		
156	16.8	209	460	Rolled bar	66	Continuous	X	
455	49	585	1290	Rolled depol. & electrolytic	28	Continuous		X
156	16.8	Insoluble		Pb-Sb	-	-		
2573	277	1560	3440	Forged balls	36	Batch	X	X
1551	167	921	2060	Forged balls	36	Batch	X	X
557	60	408	900	Forged balls	33	Batch	X	X
1505	162	Insoluble		Pb-Sb	-	-		
1486	160	Insoluble		Pb-Sb	-	-		
-	-	-		-	-	-		
-	-	-		-	-	Batch	(X)	

TABLE B-10. SOLID WASTES FROM PLATING OPERATIONS OF MODEL PLANT

Line No. and Bath	Anode Sludge		Anode Scrap		Metal Scrap[a]		Anode Bags		Filter Cake[b]		Chemicals[c]			
											Solution Components[d]		Na_2CO_3	
	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr	kg/yr	lb/yr
1) Cu	25	54	444	910	--	--	6	13	44	98	51	112	170	375
Ni	198	436	[2964]	[6536][e]	472	1000	25	55	192	423	217	478	--	--
Cr	11	25[f]	--	--	--	--	--	--	--	--	--	--	--	--
2) Cu	7	15	124	273	--	--	2	4	36	79[g]	14	31	85	188
Ni	55	122	--	--	94	200	1	2	54	119	55	121	--	--
Cr	3	6	--	--	--	--	--	--	--	--	--	--	--	--
3) Zn	113	249	565	1245	204	450[h]	--	--	15	33	15	33	766	1690
4) Zn	68	150	339	747	122	270[h]	--	--	9	20	9	20	460	1014
5) Cd	40	88	201	444	18	40	--	--	4	8	4	8	170	375
6) Cr	1	2	--	--	--	--	--	--	--	--	--	--	--	--
7) Anodizing	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8) Phosphating	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9) Electroless Ni	--	--	--	--	--	--	--	--	209	460	--	--	14,984	33,040[i]
Totals	521	1147	1673	3689	911	1960	34	74	354	780	364	803	1,651 14,984[i]	3,642 33,040[i]

a) Scrap generated by electrolytic bath purification composed of metallic impurities and metal-bath constituent.
b) Composed of 83 percent diatomaceous earth and 17 percent activated carbon.
c) Based on a 50-week year.
d) Quantity of chemicals absorbed in filter cakes and anode bags in concentrations of the bath constituents.
e) Scrap anodes are reused in Ni-bath of Line 2.
f) Composed of Pb, Sb, and CrO_3.
g) 24 kg (52 lb) are discarded filter cartridges.
h) Composed of zinc polysulfides and metallic impurities generated during the chemical-bath purification.
i) Calcium orthophosphite and calcium sulfate precipitated during the bath regeneration.

TABLE B-11. MISCELLANEOUS WASTES FROM OPERATION OF MODEL PLANT

Waste Source	Type of Waste	Amount of Waste		Mode of Disposal	Additional Manpower
		kg/yr	lb/yr[a]		
Polishing and Buffing					12
Metal removal (brass)	Solid	3,040	6,710	Landfill	
Compound[b]	Sludge	12,607	27,830	Landfill	
Wheels and buffs	Solid	3,040	6,710	Landfill	
		3,040	6,710	Used buffs to supplier	
Deburring					1
Metal removal	Wet	730	1,615	Discharged to sewer in small quantities, lost in production	
Aluminum oxide	Wet	730	1,615		
Proprietary compound	Solid	7,550	16,440		
Steel balls and shapes	Wet	945	12,080		
Grinding and Sizing[c]	Solid	2,060	4,550	Landfill	1
Chromium	Solid	380	840	To scrap dealer	
Rejects					
Steel	Solid	37,640	83,000	To scrap dealer	
Brass	Solid	2,330	5,130	To scrap dealer	
Plating Racks					1
Coating	Solid	1,615	3,560	Landfill	
Ti-rack tips	Solid	810	1,780	To scrap dealer	
Racks (brass)	Solid	1,610	3,550	To scrap dealer	
Contact buildup[d]					
Cu	Solid	160	350		
Ni	Solid	1,270	2,800		
Zn	Solid	950	2,100	To scrap dealer	
Cl	Solid	160	355		
Cr	Solid	60	135		
Degreaser[b]					0
$CHCl:CCl_2$	Sludge	2,054	4,530	Landfill	

a) Based on a 250-day year.

b) Polishing and buffing compounds are dissolved in $CHCl:CCl_2$, forming a sludge which is periodically removed.

c) Preparation for and finishing of hard chromium plating of ferrous alloys.

d) From periodic cleaning of racks.

Process Wastes

Plating solutions must be kept free of solids, particles, precipitates, and impurities, which when left in solution could cause rough deposits. Solids are removed by passing the solution through a filter medium of a porous material which is normally precoated with a filter aid, such as diatomaceous earth. In addition, activated carbon is used to remove organic materials by absorption. As the filter openings clog, the high rate of solution flow is constantly decreased, requiring frequent cleaning of the filter. The copper, nickel, and cadmium baths are continuously filtered. The zinc baths are batch filtered twice a year, while the chromium baths, anodizing, and phosphating solutions are not filtered. In order to properly size the filters, the bath volume must be calculated. For a copper strike having a cathodic current efficiency of 50 percent and depositing 2 μm (0.000075 inch) at a current density of 2.5 amp/dm^2 (25 amp/ft^2), the plating time required is 3.2 minutes. For Line 1, the process rate is 560 m^2/day (6,024 sq ft/day) or 4 m^2 (40 sq ft) per load. Assuming that each rack can carry 2 m^2 (20 sq ft) of parts to be plated, a bath volume of 1,000 gal is required if tank width and depth are 1.5 m (5 ft) each and tank length is 1.65 m (5-1/2 ft), allowing for a rack size of 0.75 x 1.2 m (2-1/2 x 4 ft). For a filtering rate of 1,350 l/m^2/hr (33-1/3 gal/sq ft/hr) the required filter area is 2.8 m^2 (30 sq ft) if the 3,785 l (1,000 gal) of solution are passed through the filter once each hour. Using a precoat of diatomaceous earth and activated carbon at a ratio of 5:1 and a loading of 667 g/m^2 (2 oz/sq ft) of filtering aid every 2 weeks, the filter cake disposal is 88 kg/yr (195 lb/yr), composed of 37 kg (81-1/2 lb) diatomaceous earth, 7.4 kg (16-1/2 lb) activated carbon, and 43.6 kg (97-1/2 lb) of hazardous plating bath chemicals, assuming that the filter coat absorbs its equal weight in plating bath plus dust and dirt.

Copper bar anodes of 1.2 m (4 ft) length and a cross section of 35 cm^2 (5.5 sq in) used in the bath weigh 39 kg (86 lb) each, when new. Assuming that half of the anodes are used up on the average, 38 anodes are required in the bath when the anode-to-cathode ratio is 1.5 to 1, weighing 737 kg (1,626 lb). The anodes are not totally consumed; they are replaced in the bath after 85 percent consumption, resulting in a total anode replacement of 627 kg (1,382 lb) every 66 days at a copper deposition rate of 9.44 kg/day (20.88 lb/day). The unusable anode scrap of 44 kg (980 lb/yr) is sold as pure copper metal.

The anode bags are reused once so that 78 bags are disposed of once a year. Each bag has an area of 0.4 m^2 (0.5 sq yd) weighing 60 g (2 oz) for a total of 6 kg/yr (13 lb/yr). Together with the anode bags 6 kg (13 lb) of bath chemicals are disposed of with the regular trash, composed of 2.0 kg/yr (4.5 lb/yr) CuCN, 2.9 kg/yr (6.3 lb/yr) NaCN, 0.2 kg/yr (0.5 lb/yr) of NaOH, and 0.9 kg/yr (1.7 lb/yr) of Na_2CO_3.

Anodes corrode with formation of a sludge which collects in the anode bags. With the assumption that 1 percent of the anodes becomes insoluble sludge, 25 kg (54 lb) are destined for disposal in a year's time.

The copper plating bath of Line 2 is equipped with a solution submersible filter. Twenty-six cartridges are used annually weighing 11.4 kg (25 lb) plus 12.3 kg (27 lb) of filter cake and 12.3 kg (27 lb) of absorbed bath chemicals.

The two zinc plating baths of Lines 3 and 4 use bagged, forged zinc ball-anodes and are batch filtered twice a year. The chromium baths are not filtered, but an anode sludge consisting of lead antimony chromate is scrubbed from the anodes once a week, amounting to 11 kg/yr (25 lb/yr) for Line 1, 3 kg/yr (6 lb/yr) for Line 2, and 1 kg/yr (2 lb/yr) for the hard chromium plating operations. With the anodes being scrubbed in a rinse tank, this waste may go to the treatment plant or the sewer.

The scrap nickel anodes of 15 percent of the total load of Line 1, or 2964 kg (6536 lb) of nickel are used in anode baskets in the nickel bath of Line 2. Consequently, no scrap nickel results from the plant operations.

The total plant operation requires the passage of 1368 racks per day, or 355,650 racks processed per year. Assuming that 1/2 of 1 percent of the racks are recoated and that the coating material, vinyl plastisol, weighs 1 kg (2 lb) per rack, then 1615 kg (3560 lb) of rack coating is disposed of annually. If each rack lasts through 1000 process cycles, then 1610 kg/yr (3550 lb/yr) of brass for a rack weight of 4.5 kg (10 lb) each are hauled from the plant to a scrap dealer. With each recoating of the racks, titanium contact tips weighing 0.45 kg (1 lb) per rack, or 810 kg (1780 lb) of titanium are also sold to a scrap dealer. With each plating cycle, metal is deposited on all exposed and submerged metal-conductors of the racks. Assuming that this amount is equal to 5 percent of all metals deposited on workpieces, 2600 kg (5740 lb) of metal per year, namely 160 kg/yr (350 lb/yr) Cu, 1270 kg/yr (2800 lb/yr) Ni, 950 kg/yr (2100 lb/yr) Zn, 160 kg/yr (355 lb/yr) Cd, and 60 kg/yr (135 lb/yr) Cr are sold for recycling.

Plating solutions are sensitive to metallic impurities which, when codeposited with the metal, have a deleterious effect on the properties of the deposit. Low current density purification, called dummying, is therefore applied to most plating baths. It could be carried out on a batch basis or continuously by cycling the plating solution through an auxiliary tank. For example, the nickel bath of Line 1 is purified by electrolysis of 0.5 amp/dm^2 (5 amp/sq ft), using 420 dm^2 (45 sq ft) of cathode area (equivalent to an electrolysis current of 0.013 amp/l [0.05 amp/gal] of solution) and depositing 1.8 kg/day (4.0 lb/day) of metal alloy consisting of nickel (the highest fraction), copper, zinc, and iron, the basis metals processed on the line.

The two zinc baths are treated twice each year by a chemical treatment of zinc dust, which displaces the more noble metals in the solution plus an addition of polysulfide. With a charge of 2 g/l (0.25 oz/gal) of each, 135 kg (300 lb) of metal, mostly copper, and 135 kg (300 lb) of metal sulfides are precipitated and removed by filtering. Alkaline cyanide baths build up carbonate concentration during the operation. When that concentration exceeds a certain value, it is common practice to remove the carbonate by freezing. Depending on geographic location of the plant, this may be accomplished by pumping the bath to an outside storage tank in the winter time or artificially cooling the bath. If such a procedure is carried out once a year and the removal rate is 45 g/l (6 oz/gal) of Na_2CO_3, then for the zinc bath of Line 3, 766 kg (1690 lb) of Na_2CO_3 are generated and must be disposed of to the waste treatment plant in form of a sludge containing all the constituents of the bath. Alternatively, the sludge may be drummed and taken to a landfill.

The electroless nickel plating bath of Line 9 has a waste disposal problem all its own. An increase of the phosphite level to above 1.2 moles/liter through oxidation of the $(H_2PO_2)^-$ ion generally requires that the bath would be discarded by returning it to the manufacturer. Because of the high volume of production (160 m^2/day) in a large volume of solution (1900 l or 500 gal) depositing 16 kg (35.2 lb) of nickel per day for a thickness of 0.00125 cm (0.0005 inch), it was decided to regenerate the bath in-house by addition of $Ni(OH)_2$, hypophosphorous acid, calcium sulfate and hydrated lime, the latter two being the first two steps in the regeneration process. The precipitated calcium orthophosphite, 40.3 kg/day (88.8 lb/day) for the amount of nickel deposited, is pressure filtered and removed, amounting to 10430 kg (23,000 lb) annually. In addition, $NaSO_4$ has to be removed by freezing. The quantity of waste disposed of is 4550 kg/yr (10,040 lb/yr). Other procedures, such as phosphite removal by ion exchange, would be more economical, producing much less waste.

Metal finishing plants normally are not 100 percent efficient. A certain number of parts are rejected on quality inspection because of defects in the coatings. With the assumption that 0.5 percent of the finished parts are rejected, for a proposed material thickness of 0.2 cm (0.075 inch) and from the production rate, 37640 kg (83,000 lb) of steel parts and 2330 kg (5130 lb) of brass parts containing Cu-Ni-Cr and/or Zn are collected and sold to a scrap dealer periodically. The cadmium and hard-chromium plating parts are assumed to be stripped and replated.

Organic Wastes

Some of the organic wastes, for example rack coatings, have been dealt with earlier in this section of the report. A degreasing operation using trichlor ($CHCl:CCl_2$) is needed to remove the bulk of the polishing and buffing compounds from the parts prior to plating. Assuming that the compounds are disposed of in a sludge containing equal amounts of the solvent, 10,700 l (2830 gal) of $CHCl:CCl_2$ are lost annually. The remaining solvent is assumed to be purified continuously in the plant by a distilling apparatus attached to the degreaser.

Conclusion

The preceding calculations are examples of the wastes generated by the model plant other than the chemical sludges from waste treatment operations. The assumptions made in the examples are the same for corresponding type processes and solutions and the total wastes which are disposed of are tabulated in the preceding Tables B-9 to B-11. In order to perform these functions, 15 employees were added to the total plant force.

PART II. CALCULATIONS OF CHEMICALS IN WASTE STREAMS FOR ELECTROPLATING AND METAL FINISHING OPERATIONS LINES 2 THROUGH 9 FOR MODEL PLANT

Line 2. Manual Racks Cu(CN)-Ni-Cr Plating Calculations

Hot Alkali Soak Clean

Make-up concentration: 8 oz/gal
Drag out rate: 5.16 gal/day
Dump cycle: 25 days
Tank volume: 600 gal
Dump rate: 24 gal/day

Daily Amounts in Drag Out & Dump Stream

$NaOH$ = (24)(2.10) = 50.4 oz/day = 3.15 lb/day
Na_2CO_3 = (24)(1.32) = 31.7 oz/day = 1.98 lb/day
Na_2SiO_3 = (24)(1.50) = 36.0 oz/day = 2.25 lb/day
$Na_2PO_4 \cdot 12H_2O$ = (24)(0.72) = 17.3 oz/day = 1.08 lb/day

Electrolytic Anodic Clean - Steel and Nonferrous Metals

Make-up concentration: 8 oz/gal
Drag out rate: 5.16 gal/day
Dump cycle: 20 days
Tank volume: 300 gal
Dump rate: 15 gal/day

Daily Amounts in Drag Out & Dump Stream

$NaOH$ = (15)(2.10) = 31.5 oz/day = 1.97 lb/day
Na_2CO_3 = (15)(0.78) = 11.7 oz/day = 0.73 lb/day
Na_2SiO_3 = (15)(2.40) = 36.0 oz/day = 2.25 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (15)(0.60) = 9.0 oz/day = 0.55 lb/day

Sulfuric Acid Dip

Make-up concentration: 45 g/l
Drag out rate: 5.16 gal/day
Dump cycle: 10 days
Tank volume: 200 gal
Dump rate: 20 gal/day
Workpieces: 70 percent steel; 30 percent brass

It was assumed that 15 percent of the acid was used up in pickling the workpieces. The acid concentration is maintained by the periodic addition of fresh acid to replace the drag out acid. The quantity of unreacted H_2SO_4 that leaves in the rinse waters and is dumped is as follows:

$$(5.16 + 20)(38.25)(3.78) = 3,643 \text{ g/day or } 8.04 \text{ lb/day.}$$

The amount of metal in the rinse and dump streams is as follows:

$$(25.16)(6.75)(3.78) = 642 \text{ g } H_2SO_4\text{/day reacted with metals.}$$

70 percent reacted with iron and 30 percent with brass.

$$\frac{(642)(0.70)}{1.76} = 255 \text{ g/day} = 0.564 \text{ lb/day of iron.}$$

$$\frac{(642)(0.30)}{1.53} = 126 \text{ g/day}$$

88.1 g/day = 0.194 lb/day of copper

37.9 g/day = 0.084 lb/day of zinc.

Sulfuric Acid Dip (After Cu(CN) Plating)

As on Line 1, this dip was assumed to dissolve a negligible quantity of copper plate; no additions of fresh acid are made to this tank.

Drag out rate:	5.16 gal/day
Dump cycle:	10 days
Tank volume:	200 gal
Dump rate:	20 gal/day

Quantity of acid leaving in the drag out and dump streams is:

$$(20)(107)(3.78) = 8100 \text{ g/day} = 17.88 \text{ lb/day of sulfuric acid.}$$

Line 3. Zinc Automatic Rack Plating (+ Chromating) Calculations

Electrolytic Anodic Clean (Steel)

Make-up concentration: 8 oz/gal
Drag out rate: 25.8 gal/day
Dump cycle: 15 days
Tank volume: 500 gal
Dump rate: 33.33 gal/day

Daily Amounts in Drag Out and Dump Stream

$NaOH$ = (33.33)(3.0) = 100.0 oz/day = 6.25 lb/day
Na_2CO_3 = (33.33)(2.4) = 80.00 oz/day = 5.00 lb/day
Na_2SiO_3 = (33.33)(0.24) = 8.00 oz/day = 0.50 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (33.33)(0.30) = 10.0 oz/day = 0.63 lb/day

Concentrated Hydrochloric Acid Dip

Make-up concentration: 111 g/l
Drag out rate: 25.8 gal/day
Dump cycle: 25 days
Tank volume: 250 gal
Dump rate: 10 gal/day

It will be assumed that the original acid will be used up by reacting 20 percent of it with Fe and disposing of the remaining 80 percent as unreacted acid in the dump and drag out streams.

Total acid at start = (111)(250)(3.785) = 104,895 g/day
= 231.6 lb/day

Acid reacted with Fe = 20,979 g = $\frac{46.3 \text{ lb}}{25 \text{ days}}$ = 1.85 lb/day

Acid unreacted = 83,916 g = $\frac{185.2 \text{ lb}}{25 \text{ days}}$ = 7.41 lb/day

The quantity of Fe dissolved = $\frac{1.85 \text{ lb/day}}{1.306}$ = 1.42 lb/day

Where 1.306 is the ratio of HCl to Fe according to the equation

$$Fe^{o} + 2H^{+} \rightarrow Fe^{2+} + H_2\uparrow$$

Caustic Dip

Make-up concentration: 1.0 oz/gal
Drag out rate: 25.8 gal/day
Dump cycle: 5 days
Tank volume: 250 gal
Dump rate: 50 gal/day

Quantity of NaOH leaving in the drag out and dump:

(1.0)(7.5)(50)(3.78) = 1,418 g NaOH/day = 3.12 lb/day.

Chromate Dip

Make-up concentration: 15 g/l $Na_2Cr_2O_7 \cdot 2H_2O$ (2 oz/gal)
7.5 g/l HNO_3 (1 oz/gal).

It was assumed that 1/2 of the original Cr^{+6} content winds up on the workpieces. It was also assumed that the total zinc dissolved during the chromating operation is equivalent to 1/2 the nitric acid originally present.

Amount of Cr^{+6} Leaving in Drag Out and Dump

M.W. of $Na_2Cr_2O_7 \cdot 2H_2O$ = 298.05

$$\%Cr^{+6} = \frac{2(52.01)}{298.05} \times 100 = 34.9 \text{ percent.}$$

Drag out rate:	25.8 gal/day
Dump cycle:	5 days
Tank volume:	250 gal
Dump rate:	50 gal/day

Quantity of dichromate leaving = (50)(3.78)(7.5) = 1,416 g/day

= 3.12 lb/day.

Quantity of Cr^{+6} leaving = 3.12(0.349) = 1.088 lb/day.

Quantity of unreacted nitric acid leaving in the drag out and dump:

(3.75)(50)(3.78) = 709 g HNO_3/day = 1.56 lb HNO_3/day.

Quantity of dissolved zinc metal leaving in the drag out and dump:

$$4Zn^o + NO_3^- + 10H^+ \rightarrow 4Zn^{2+} + NH_4^+ + 3H_2O$$

1 gram Zn requires 2.41 g HNO_3, then

$$\left(\frac{3.75}{2.41}\right)(50)(3.78) = 294 \text{ g/day} = 0.648 \text{ lb/day.}$$

Zinc dissolves in the nitric acid mainly by hydrogen ion displacement.

$$Zn^o + 2HNO_3 \rightarrow H_2 + 2NO_3^- + Zn^{++}$$

Line 4. Automatic Barrel Zinc(CN) Calculations

Hot Alkali Soak Clean

Make-up concentration: 8.0 oz/gal
Drag out rate: 25.8 gal/day
Dump cycle: 10 days
Tank volume: 600 gal
Dump rate: 60 gal/day

Daily Amounts in Drag Out and Dump Stream

NaOH = (60)(2.10) = 126 oz/day = 7.88 lb/day
Na_2CO_3 = (60)(1.32) = 79.2 oz/day = 4.95 lb/day
Na_2SiO_3 = (60)(1.50) = 90.0 oz/day = 5.63 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (60)(0.78) = 46.8 oz/day = 2.93 lb/day

Concentrated Hydrochloric Acid Dip

Make-up concentration: 111 g/l
Drag out rate: 25.8 gal/day
Dump cycle: 15 days
Tank volume: 200 gal
Dump rate: 13.33 gal/day

It will be assumed that the original acid will be used up by reacting 20 percent of it with Fe and disposing of the remaining 80 percent as unreacted acid in the dump and drag out stream.

Total acid at start = (111)(200)(3.78) = 83,916 g = 185.3 lb

$$\text{Acid reacted with Fe} = 16{,}783 \text{ g} = \frac{37.05 \text{ lb}}{15 \text{ days}} = 2.47 \text{ lb/day}$$

$$\text{Acid unreacted} = 67{,}133 = \frac{148.2 \text{ lb}}{15 \text{ days}} = 9.88 \text{ lb/day}$$

$$\text{The quantity of Fe dissolved} = \frac{2.47 \text{ lb/day}}{1.306} = 1.89 \text{ lb/day.}$$

Caustic Dip

Make-up concentration: 1.0 oz/gal NaOH
Drag out rate: 25.8 gal/day
Dump cycle: 5 days
Tank volume: 200 gal
Dump rate: 40 gal/day

Quantity of NaOH leaving in the drag out and dump stream:

(1)(7.5)(40)(3.78) = 1,134 g NaOH/day = 2.50 lb NaOH/day.

Nitric Acid Dip

Make-up concentration:	51 g/l
Drag out rate:	25.8 gal/day
Dump cycle:	5 days
Tank volume:	200 gal
Dump rate:	40 gal/day

Quantity of acid leaving in the drag out and dump stream:

(51.0)(40)(3.78) = 7,711 g/day = 17.02 lb/day.

Chromate Dip

Make-up concentration: 15 g/l $Na_2Cr_2O_7 \cdot 2H_2O$

7.5 g/l HNO_3.

It was assumed that 1/2 of the original Cr^{+6} in the bath winds up on the workpiece surfaces. It was also assumed that the total zinc dissolved during the chromating operation is equivalent to 1/2 the nitric acid present in the original bath.

Amount Cr^{+6} Leaving in Drag Out and Dump

Drag out rate:	25.8 gal/day
Dump cycle:	5 days
Tank volume:	200 gal
Dump rate:	40 gal/day

Quantity of dichromate leaving:

(40)(3.78)(7.5) = 1,136 g/day = 2.496 lb/day.

Quantity of Cr^{+6} leaving = (2.496)(0.349) = 0.872 lb/day.

Quantity of dissolved zinc leaving in the dragout and dump:

1 gram Zn requires 2.41 g HNO_3

$\left(\frac{3.75}{2.41}\right) = (40)(3.78) = 235$ g/day = 0.52 lb/day.

Quantity of unreacted HNO_3 leaving in the drag out and dump:

(3.75)(40)(3.78) = 567 g/day = 1.25 lb/day.

Line 5. Manual Barrel Cadmium(CN)
Calculations

Cathodic Alkaline Clean (Steel)

Make-up concentration: 8.0 oz/gal
Drag out rate: 8.6 gal/day
Dump cycle: 10 days
Tank volume: 400 gal
Dump rate: 40 gal/day

Daily Amounts in Drag Out and Dump Stream

NaOH = (40)(3.0) = 120 oz/day = 7.5 lb/day
Na_2CO_3 = (40)(24) = 96.0 oz/day = 6.0 lb/day
Na_2SiO_3 = (40)(0.24) = 9.60 oz/day = 0.60 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (40)(0.30) = 12.0 oz/day = 0.75 lb/day

Concentrated Hydrochloric Acid Dip

Make-up concentration: 111 g/l
Drag out rate: 8.6 gal/day
Dump cycle: 10 days
Tank volume: 200 gal
Dump rate: 20 gal/day

It was assumed that the original acid is used up by reacting 20 percent of it with Fe and disposing of the remaining 80 percent as unreacted acid in the dump and drag out stream.

Total acid at start = (111)(200)(3.78) = 83,916 g = 185.3 lb

Acid reacted with Fe = 16,783 g = $\frac{37.05 \text{ lb}}{10 \text{ days}}$ = 3.705 lb/day

Acid unreacted = 67,133 = $\frac{148.2 \text{ lb}}{10 \text{ days}}$ = 14.82 lb/day

The quantity of Fe dissolved = $\frac{3.705 \text{ lb/day}}{1.306}$ = 2.84 lb/day.

Caustic Dip

Make-up concentration: 2 oz/gal
Drag out rate: 8.6 gal/day
Dump cycle: 5 days
Tank volume: 200 gal
Dump rate: 40 gal/day

Quantity of NaOH leaving in the drag out and dump stream:

(2)(7.5)(40)(3.78) = 2,268 g/day = 5.01 lb/day.

Chromate Dip

Make-up concentration: 15 g/l $Na_2Cr_2O_7 \cdot 2H_2O$

7.5 g/l HNO_3.

It was assumed that 1/2 of the original Cr^{+6} winds up on the Cd-plated workpieces. It was also assumed that the total cadmium dissolved during the chromating operation is equivalent to 1/2 the nitric acid present in the original bath.

Amount of Cr^{+6} Leaving in Drag Out and Dump

Drag out rate:	8.6 gal/day
Dump cycle:	10 days
Tank volume:	200 gal
Dump rate:	20 gal/day

Quantity of dichromate leaving: (20)(3.78)(7.5) = 567 g/day

= 1.252 lb/day.

Quantity of Cr^{+6} leaving = (1.252)(0.349) = 0.437 lb/day.

Quantity of dissolved cadmium metal leaving in the drag out and dump:

1 gram Cd requires 1.12 g of HNO_3

$\left(\frac{3.75}{1.12}\right)(20)(3.78)$ = 253 g/day = 0.56 lb/day.

Quantity of unreacted nitric acid leaving in the drag out and dump:

(3.75)(20)(3.78) = 284 g/day = 0.626 lb/day.

Line 6. Manual Rack Hard Chromium
Calculations

Cathodic Alkaline Clean (Steel)

Make-up concentration: 8 oz/gal
Drag out rate: 2.60 gal/day
Dump cycle: 20 days
Tank volume: 200 gal
Dump rate: 10 gal/day

Daily Amounts in Drag Out and Dump Stream

NaOH = (10)(3.0) = 30.0 oz/day = 1.875 lb/day
Na_2CO_3 = (10)(2.4) = 24.0 oz/day = 1.50 lb/day
Na_2SiO_3 = (10)(0.24) = 2.40 oz/day = 0.150 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (10)(0.30) = 3.00 oz/day = 0.188 lb/day.

Anodic Sulfuric Acid Treatment

Make-up concentration: 960 g/l
Drag out rate: 2.60 gal/day
Dump cycle: 60 days
Tank volume: 200 gal
Dump rate: 3.33 gal/day

It was assumed that 20 percent of the original sulfuric acid present is used to convert steel (Fe) to ferrous sulfates

1 g steel reacts with 1.76 g of H_2SO_4

Quantity of Fe in the drag out and dump:

$$(0.20)\left(\frac{960}{1.76}\right)(3.33)(3.78) = 1{,}373 \text{ g/day} = 3.03 \text{ lb/day.}$$

Quantity of unreacted sulfuric acid in the drag out and dump:

$$(0.8)(960)(3.33)(3.78) = 9{,}667 \text{ g/day} = 21.34 \text{ lb/day.}$$

Line 7. Manual Rack Anodizing Calculations

Hot Alkali Soak Clean (Aluminum)

Make-up concentration:	8 oz/gal
Drag out rate:	19.37 gal/day
Dump cycle:	15 days
Tank volume:	800 gal
Dump rate:	53.33 gal/day

Item	Wt. %	Orig. Comp. oz/gal	75% Residual Comp., oz/gal
Na_2SiO_3	40	3.2	2.7
Na_2CO_3	45	3.6	2.7
$Na_3PO_4 \cdot 12H_2O$	10	0.8	0.6
Surfactant	5	0.4	0.3

Daily Amounts in Drag Out and Dump Stream

Na_2CO_3 = (53.33)(2.4) = 128 oz/day = 8.0 lb/day

Na_2SiO_3 = (53.33)(2.7) = 144 oz/day = 9.0 lb/day

$Na_3PO_4 \cdot 12H_2O$ = (53.33)(0.6) = 32 oz/day = 2.0 lb/day.

Caustic Etch

Make-up concentration:	53 g/l NaOH
Drag out rate:	19.37 gal/day
Dump cycle:	7.5 days
Tank volume:	400 gal
Dump rate:	53.33 gal/day

It will be assumed that 20 percent of the NaOH is used up in etching the aluminum workpieces. Quantity of NaOH leaving in the drag out and dump:

(53)(0.8)(53.33)(3.78) = 8,547 g/day = 18.87 lb/day.

Quantity of Al leaving in the drag out and dump:

$$2\ Al + 2OH^- + 2\ H_2O \rightarrow 2\ AlO_2^- + 3H_2\uparrow$$

1 g Al requires 1.48 g NaOH for dissolution.

$$\frac{(53)(0.2)(53.33)(3.78)}{(1.48)} = \frac{1444\ g/day}{453\ g/lb} = 3.187\ lb/day.$$

Nitric Acid Desmut

Make-up concentration: 100 g/l HNO_3
Drag out rate: 19.37 gal/day
Dump cycle: 20 days
Tank volume: 400 gal
Dump rate: 20 gal/day

The desmut serves to remove small quantities of materials such as copper, manganese, and other elements from the aluminum surface. It will be assumed that at the time of dumping, 5 percent of the original acid present was used up in dissolving small amounts of copper and manganese with 60 percent used for copper and 40 percent for Mn.

$$3\ Cu^{o} + 2\ NO_3^- + 8H^+ \rightarrow 3\ Cu^{2+} + 2\ NO\uparrow + 4\ H_2O$$

$$3\ Mn^{o} + 2\ NO_3^- + 8H^+ \rightarrow 3\ Mn^{2+} + 2\ NO\uparrow + 4\ H_2O$$

1 g Cu requires: 0.66 g HNO_3

1 g Mn requires: 0.77 g HNO_3.

Quantity of unreacted HNO_3 leaving in the drag out and dump:

(95)(20)(3.78) = 7,182 g/day = 15.85 lb/day.

Quantity of Cu and Mn leaving in the drag out and dump:

$$\frac{(20)(3.0)(3.78)}{(0.66)} = 344 \text{ g/day} = 0.759 \text{ lb/day of copper}$$

$$\frac{(20)(2.0)(3.78)}{(0.77)} = 196 \text{ g/day} = 0.433 \text{ lb/day of manganese.}$$

Bright Dip

The bright dip solution employs save rinses with most of the acids recovered and sold to a fertilizer manufacturer as indicated in Table A-2, Line 7.

Anodize

The aluminum anodizing solution is discarded when the aluminum concentration reaches 12 g/l.

Make-up concentration: 165 g/l H_2SO_4
Drag out rate: 19.37 gal/day
Dump cycle: 20 days
Tank volume: 3000 gal
Dump rate: 150 gal/day

Quantity of sulfuric acid reacting with aluminum in the anodizing operation:

$2\ Al^{o} + 6\ H^{+} \rightarrow 2\ Al^{3+} + 3\ H_2\uparrow$

1 g Al requires 5.45 g H_2SO_4 for reaction, and 12 g

require (12)(5.45) = 65.4 g H_2SO_4/l.

Quantity of unreacted sulfuric acid in the drag out and dump:

(99.6)(150)(3.78) = 56,473 g/day = 124.7 lb/day.

Quantity of aluminum leaving in the drag out and dump:

(12.0)(150)(3.78) = 6,804 g/day = 15.02 lb/day.

Nickel Acetate Seal

Make-up concentration:	10 g/l $Ni(C_2H_3O_2)_2 \cdot 4H_2O$
Drag out rate:	19.37 gal/day
Dump cycle:	5 days
Tank volume:	400 gal
Dump rate:	80 gal/day

It will be assumed that 1/2 of the nickel acetate is used up on sealing the anodized aluminum surfaces. Quantity of nickel leaving in the drag out and dump:

$$\frac{Ni}{Ni(C_2H_3O_2)_2 \cdot 4H_2O} = \frac{58.69}{248.84} = 23.6 \text{ percent Ni}$$

(50)(0.236)(80)(3.78) = 357 g/day = 0.788 lb/day.

Line 8. Automatic Barrel Zinc Phosphating Calculations

Hot Alkaline Soak Clean (Steel)

Make-up concentration: 8.0 oz/gal
Drag out rate: 21.52 gal/day
Dump cycle: 20 days
Tank volume: 250 gal
Dump rate: 12.5 gal/day

Daily Amounts in Drag Out and Dump Stream

$NaOH$ = (12.5)(2.10) = 26.25 oz/day = 1.64 lb/day
Na_2CO_3 = (12.5)(1.32) = 16.50 oz/day = 1.03 lb/day
Na_2SiO_2 = (12.5)(1.50) = 18.75 oz/day = 1.17 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (12.5)(12.5) = 9.00 oz/day = 0.56 lb/day.

Hydrochloric Acid Pickle

Make-up concentration: 75 g/l
Drag out rate: 21.52 gal/day
Dump cycle: 10 days
Tank volume: 250 gal
Dump rate: 25 gal/day

It will be assumed that the original acid will be used up by reacting 20 percent of it with Fe and disposing of the remaining 80 percent as unreacted acid in the dump and drag out stream.

Quantity of unreacted HCl in the drag out and dump stream:

(75)(0.8)(25)(3.78) = 5,670 g/day = 12.52 lb/day.

Quantity of Fe leaving in the drag out and dump stream:

$$\frac{(75)(0.2)}{1.306}(25)(3.78) = 1{,}085 \text{ g/day} = 2.40 \text{ lb/day.}$$

Zinc Phosphate

It will be assumed that 1/2 of the phosphating solution is used up and retained in the coating on the steel workpieces:

Make-up concentratin: 42 g/l $H_3PO_4 \cdot Zn_3(PO_4)_2$
Drag out rate: 21.52 gal/day
Dump cycle: 15 days
Tank volume: 250 gal
Dump rate: 16.67 gal/day

Quantity of unreacted H_3PO_4 leaving in the drag out and dump stream:

$$\frac{H_3PO_4}{H_3PO_4 \cdot Zn_3(PO_4)_2} = \frac{98.0}{484.1} = 0.202$$

(21)(0.202)(16.67)(3.78) = 267.3 g/day = 0.59 lb/day.

Quantity of $Zn_3(PO_4)_2$ leaving in the drag out and dump stream:

(21)(0.798)(16.67)(3.78) = 1,056 g/day = 2.33 lb/day.

Quantity of Zn leaving in the drag out and dump stream:

$$\frac{3(Zn)}{Zn_3(PO_4)_2} = \frac{196.1}{386.1} = 0.508 \quad (2.33)(0.508) = 1.18 \text{ lb/day.}$$

Hot Dip Seal

Make-up concentration: 0.25 g/l CrO_3
Drag out rate: 21.52 gal/day
Dump cycle: 5 days
Tank volume: 250 gal
Dump rate: 50 gal/day

It will be assumed that 1/2 of the chromic acid solution winds up on the sealed coating.

Quantity of CrO_3 solution leaving in the dump stream:

(0.125)(50)(3.78) = 23.6 g/day = 0.052 lb/day.

Quantity of Cr^{+6} leaving in the dump stream:

(0.052)(0.52) = 0.027 lb/day.

Line 9. Manual Electroless Rack Nickel Calculations

Hot Alkali Soak Clean (Steel)

Make-up concentration: 8.0 oz/gal
Drag out rate: 5.16 gal/day
Dump cycle: 10 days
Tank volume: 200 gal
Dump rate: 20 gal/day

Daily Amounts in Drag out and Dump Stream

NaOH = (20)(2.10) = 42.0 oz/day = 2.63 lb/day
Na_2CO_3 = (20)(1.32) = 26.4 oz/day = 1.65 lb/day
Na_2SiO_3 = (20)(1.50) = 30.0 oz/day = 1.88 lb/day
$Na_3PO_4 \cdot 12H_2O$ = (20)(0.72) = 14.4 oz/day = 0.90 lb/day.

Hydrochloric Acid Dip

Make-up concentration: 240 g/l
Drag out rate: 5.16 gal/hr
Dump cycle: 15 days
Tank volume: 200 gal
Dump rate: 13.33 gal/day

It will be assumed that the original acid is used up by reacting 20 percent of it with Fe and disposing of the remaining 80 percent as unreacted acid in the dump and drag out stream.

Quantity of unreacted acid leaving in the drag out and dump:

(240)(0.80)(13.33)(3.78) = 9,674 g/day = 21.36 lb/day.

Quantity of Fe leaving in the drag out and dump:

$$\frac{(240)(0.20)}{1.306}(13.33)(3.78) = 1{,}852 \text{ g/day} = 4.09 \text{ lb/day.}$$

PART III. CALCULATIONS OF CHEMICALS IN WASTE STREAMS ORIGINATING FROM PLATING AND/OR PROCESS BATHS THAT ARE NOT DUMPED FOR LINES 2 THROUGH 9 FOR MODEL PLANT

Line 2 - Calculations

The quantity of chemicals dragged out from the three plating baths on Line 2 and carried away in the rinse waters are given below:

Copper Cyanide

Cu(CN): (5.0)(7.5)(19.53) = 732 g/day = 1.618 lb/day
NaCN: (7.0)(7.5)(19.53) = 1,025 g/day = 2,263 lb/day
NaOH: (0.5)(7.5)(19.53) = 73.2 g/day = 0.162 lb/day
Na_2CO_3: (2.0)(7.5)(19.53) = 293 g/day = 0.647 lb/day

Nickel Bath

$NiSO_4 \cdot 6H_2O$: (40.0)(7.5)(19.53) = 5,856 g/day = 12.93 lb/day
$NiCl_2 \cdot 6H_2O$: (6.0)(7.5)(19.53) = 879 g/day = 1.940 lb/day
H_3BO_3: (5.0)(7.5)(19.53) = 732 g/day = 1.618 lb/day

Chromium Bath

CrO_3: (45)(7.5)(19.53) = 6,591 g/day = 14.55 lb/day
H_2SO_4: (0.45)(7.5)(19.53) = 65.9 g/day = 0.146 lb/day

Taking into account the quantity of CrO_3 used up providing the chromium metal plated out, the total CrO_3 consumption is:

(14.55)(1.15) = 16.73 lb/day.

Line 3 - Calculations

The quantity of chemicals dragged out from the zinc plating bath and carried away in the rinse water are as follows:

Zn: (40)(25.8)(3.78) = 3,901 g/day = 8.61 lb/day
ZnO: 3,901/0.803 = 4,858 g/day = 10.72 lb/day
NaOH: (90)(25.8)(3.78) = 8,777 g/day = 19.38 lb/day
NaCN: (90)(25.8)(3.78) = 8,777 g/day = 19.38 lb/day.

Line 4 - Calculations

The same values shown above for Line 3 apply to Line 4 operations.

Line 5 - Calculations

The quantity of chemicals dragged out from the cadmium plating bath and carried away in the rinse water are as follows:

Cd: (2.66)(7.5)(32.55) = 649 g/day = 1.433 lb/day
CdO: 649/0.875 = 742 g day = 1.637 lb/day
NaCN: (13.3)(7.5)(32.55) = 3247 g/day = 7.17 lb/day
NaOH: (1.9)(7.5)(32.55) = 464 g/day = 1.024 lb/day
Na_2CO_3: (7.0)(7.5)(32.55) = 1709 g/day = 3.772 lb/day.

The values shown below represent the quantity of chemicals that are required for chromating the cadmium plated parts:

$Na_2Cr_2O_7 \cdot 2H_2O$: (2.0)(7.5)(32.55) = 488 g/day = 1.078 lb/day
HNO_3: (1.0)(7.5)(32.55) = 244 g/day = 0.539 lb/day.

Line 6 - Calculations

The quantity of chemicals dragged out from the chromium plating bath and carried away in the rinse waters are as follows:

CrO_3: (45.0)(7.5)(9.84) = 3321 g/day = 7.33 lb/day
H_2SO_4: (0.5)(7.5)(9.84) = 36.9 g/day = 0.081 lb/day.

It will be assumed that 30 percent of the CrO_3 is used up to provide the chromium metal to be plated out. Therefore, the total requirement of CrO_3 is:

(7.33)(1.30) = 9.53 lb/day.

Line 7 - Calculations

The quantity of chemicals dragged out from the bright dip and carried away in the rinse waters are as follows:

Combined acids: 206 g/l = 1.717 lb/gal
H_3PO_4: (206)(67/70)(19.37)(3.78) = 14,437 g/day = 31.87 lb/day
HNO_3: (206)(3/70)(19.37)(3.78) = 646 g/day = 1.427 lb/day.

It will be assumed that 2 g/l of aluminum are present in the last bright dip save tank. The quantity of aluminum leaving in the rinses is:

(2.0)(19.37)(3.78) = 146 g/day = 0.323 lb/day.

Line 9 - Calculations

The quantity of chemicals dragged out from the electroless nickel plating bath and carried away in the rinse waters is as follows:

$NiSO_4 \cdot 7H_2O$: (30)(5.16)(3.78) = 585 g/day = 1.292 lb/day
$NaH_2PO_2 \cdot 2H_2O$: (10)(5.16)(3.78) = 195 g/day = 0.431 lb/day
$NaC_2H_3O_2 \cdot 3H_2O$: (10)(5.16)(3.78) = 195 g/day = 0.431 lb/day.

The spent electroless nickel solution is regenerated at the plant.

APPENDIX C

MODEL PLANT B (16 EMPLOYEES)

APPENDIX C - MODEL PLANT B (16 EMPLOYEES)

SOLID WASTES FROM A MODEL ELECTROPLATING AND METAL FINISHING PLANT

Small-Size Job Shop, Model B Employing from 5 to 25 Persons

Chemical Waste Treatment

The following calculations of wastes produced and materials consumed are the same as those employed for the plating shop with 38 employees representing the medium-size job shop. The electrodeposition of copper, nickel, chromium, and zinc represents about two-thirds of the plant capacity. The other operations are cadmium, aluminum anodizing, and phosphating. The total employment is 16.

Model Plant "B" (Small) To Represent Job Shops with from 5 to 25 Employees

Assumptions

Dragout rate
Rack lines = 12.22 1/100 m^2 (3.0 gal/1000 ft^2)
Barrel lines = 20.37 1/100 m^2 (5.0 gal/1000 ft^2)

Rinsing efficiency = 70 percent

Allowable dissolved solids in rinse:
750 mg/1 from cleaners, dips, etc.
37 mg/1 from metal deposition solution
15 mg/1 from chromium plating solution.

TABLE C-1. PLANT OPERATIONS

Line or Operation	Assumed Production Rate,		Processing Rate,		Rinse[(1)] Water Allowed,		Employees
	m^2/day	ft^2/day	m^2/day	ft^2/day	l/day	gal/day	Rack, Unrack, Plating, etc.
(1) Automatic rack Cu(CN)-Ni-Cr	320	3,440	960	10,328	76,800	20,280	4
(2) Manual rack Cu(CN)-Ni-Cr	120	1,288	360	3,872	28,800	7,600	2
(3) Automatic barrel Zn(CN) + chromating	280	3,016	560	6,024	44,800	11,840	2
(4) Manual barrel Cd(w) + chromating	160	1,720	320	3,440	25,600	6,760	1
(5) Manual rack Al anodizing (+ bright dip + nickel acetate seal)	160	1,720	480	5,168	38,400	10,160	2
(6) Automatic barrel Zn-phosphating	400	4,304	400	4,304	32,000	8,440	2
Combined lines	1,440	15,488	3,080	33,136	246,400	65,080	13
Management							1
Supervision-maintenance							1
Clerical							1
Total employment							16

(1) Based on a water use of 80 l/m^2 (1964 gal/1000 sq ft).

Line 1 - Automatic rack Cu(CN)-Ni-Cr, 320 m^2/day (3444 ft^2/day)
Plating 70 percent steel and 30 percent brass.
Dragout = 39.06 l/day (10.32 gal/day).

Hot Alkali Soak Clean:	8 oz/gal	Single rinse = 150 gal/hr
	Tank volume = 1200 gal	
	Dump frequency = 25 days	
Electrolytic Anodic Clean:	8 oz/gal	Single rinse = 150 gal/hr
	Tank volume = 600 gal	
	Dump frequency = 15 days	
Sulfuric Acid Pickel:	6 oz/gal	Single rinse = 120 gal/hr
	Tank volume = 300 gal	
	Dump frequency = 10 days	
Cu(CN) Plate:	Cu(CN)	5 oz/gal
	NaCN	7 oz/gal
	NaOH	0.5 oz/gal
	Na_2CO_3	2.0 oz/gal
	2-tank counter current rinse = 100 gal/hr	
Sulfuric Acid Dip:	10 percent (107 g/l)	
	Tank volume = 300 gal	
	Dump frequency = 10 days	
Nickel plate:	$NiSO_4 \cdot 6H_2O$	40 oz/gal
	$NiCl_2 \cdot 6H_2O$	6 oz/gal
	H_3BO_3	5 oz/gal
	2-tank counter current rinse = 150 gal/hr	
Chromium Plate:	CrO_3	45 oz/gal
	H_2SO_4	0.45 oz/gal
	2-tank counter current rinse = 280 gal/hr	

Total flow = 36,800 l/day (9720 gal/day)
Acid-alkali stream = 25,290 l/day (6680 gal/day)(1200 gal/day containing Ni)
Cyanide stream = 3,030 l/day (800 gal/day)
Chromium stream = 8,480 l/day (2,240 gal/day)

Line 2 - Manual rack Cu(CN)-Ni-Cr, 120 m^2/day (1288 ft^2/day)
Plating 70 percent steel, 30 percent brass
Dragout = 14.53 l/day (3.84 gal/day)

Hot Alkali Soak Clean: 8 oz/gal Single rinse = 60 gal/hr
Total volume = 450 gal
Dump frequency = 25 days

Electrolytic Anodic Clean: 8 oz/gal Single rinse = 60 gal/hr
Tank volume = 225 gal
Dump frequency = 20 days

Sulfuric Acid Pickle: 6 oz/gal Single rinse = 45 gal/hr
Tank volume = 115 gal
Dump frequency = 10 days

Cu(CN) Plate: Composition as Line 1
2-tank counter current rinse = 40 gal/hr

Sulfuric Acid Dip: 10 percent (107 g/l) Single rinse = 100 gal/hr
Tank volume = 115 gal
Dump frequency = 10 days

Nickel Plate: Composition as Line 1
2-tank counter current rinse = 60 gal/hr

Chromium Plate: Composition as Line 1
2-tank counter current rinse = 105 gal/hr

Total flow = 14,230 l/day (3760 gal/day)
Acid-alkali stream = 9,840 l/day (2600 gal/day)
Cyanide stream = 1,210 l/day (320 gal/day)
Chromium stream = 3,180 l/day (840 gal/day)

Line 3 - Automatic barrel Zn(CN) + chromating, 280 m^2/day (3016 ft^2/day)
Plating steel
Dragout = 57.32 l/day (15.12 gal/day)

Hot Alkali Soak Clean: 8 oz/gal Single rinse = 220 gal/hr
Tank volume = 350 gal
Dump frequency = 10 days

Hydrochloric Acid Dip: 30 vol % (20° Be) 111 g/l Single rinse = 400 gal/hr
Tank volume = 120 gal
Dump frequency = 15 days

Caustic Dip: NaOH 1 oz/gal No rinse
Tank volume = 120 gal
Dump frequency = 5 days

Zinc (CN) Plate: Zn 40 g/l
NaOH 90 g/l
NaCN 90 g/l
2-tank counter current rinse = 210 gal/hr

Nitric Acid Dip 15 vol % HNO_3, 51 g/l No rinse
Tank volume = 120 gal
Dump frequency = 5 days

Chromate Conversion: $Na_2Cr_2O_7 \cdot 2H_2O$ 2.0 oz/gal
HNO_7 1.0 oz/gal
Tank volume = 120 gal
Dump frequency = 5 days
2-tank counter current rinse = 65 gal/hr

Total flow = 27,100 l/day (7160 gal/day)
Acid-alkali stream = 18,770 l/day (4960 gal/day)
Cyanide stream = 6,360 l/day (1680 gal/day)
Chromium stream = 1,970 l/day (520 gal/day)

Line 4 - Manual barrel Cd(CN) + chromating, 160 m^2/day (1720 ft^2/day)
Plating steel
Dragout = 32.70 l/day (8.64 gal/day)

Electrolytic Clean: 8 oz/gal Single rinse = 130 gal/hr
Tank volume = 400 gal
Dump frequency = 10 days

Hydrochloric Acid Dip: 30 vol % (20°Be) 111 g/l Single rinse = 235 gal/hr
Tank volume = 200 gal
Dump frequency = 10 days

Caustic Dip: NaOH = 2 oz/gal Single rinse = 35 gal/hr
Tank volume = 200 gal
Dump frequency = 5 days

Cadmium (CN) Plate: Cd = 2.66 oz/gal
NaCN = 13.3 oz/gal
NaOH = 1.9 oz/gal
Na_2CO_3 = 7.0 oz/gal
2-tank counter current rinse = 115 gal/hr

Chromate Conversion: Composition as Line 3
2-tank counter current rinse = 40 gal/hr
Tank volume = 200 gal
Dump frequency = 10 days

Total flow = 16,805 l/day (4440 gal/day)
Acid-alkali stream = 12,110 l/day (3200 gal/day)
Cyanide stream = 3,485 l/day (920 gal/day)
Chromium stream = 1,210 l/day (320 gal/day)

Line 5 - Manual rack Al-anodizing, 160 m^2/day (1720 ft^2/day)
Dragout = 19.68 l/day (5.20 gal/day)

Alkali Soak Cleaner: 8 oz/gal Single rinse = 75 gal/hr
Tank volume = 200 gal
Dump frequency = 15 days

Caustic Etch: 5% NaOH (53 g/l) Single rinse = 65 gal/hr
Tank volume = 100 gal
Dump frequency = 7.5 days

Desmut: HNO_3 = 100 g/l Single rinse = 125 gal/hr
Tank volume = 100 gal
Dump frequency = 20 days

Bright Dip: $\left.\begin{array}{r}67\%\ H_3PO_4\\ 3\%\ HNO_3\end{array}\right\}$ (206 g/l total)
2-tank counter current rinse = 70 gal/hr

Anodizing: 15% H_2SO_4
2-tank counter current rinse = 65 gal/hr
Tank volume = 800 gal
Dump frequency = 12.5 days

Nickel Acetate Seal: 10 g/l Single rinse = 250 gal/hr
Tank volume = 200 gal
Dump frequency = 5 days

Total flow to acid-alkali stream = 19,680 l/day (5200 gal/day)

ne 6 - Automatic barrel zinc-phosphating, 400 m^2/day (4304 ft^2/day)
Basic metal - steel
Dragout = 81.76 l/day (21.6 gal/day)

Alkaline Soak Cleaner: 8 oz/gal Single rinse = 310 gal/hr
Tank volume = 250 gal
Dump frequency = 20 days

Acid Pickle: 20% HCl (20° Be = 75 g/l) Single rinse = 390 gal/hr
Tank volume = 250 gal
Dump frequency = 10 days

Zinc Phosphate: $H_3PO_4 \cdot Zn_3(PO_4)_2$ = 42 g/l
2-tank counter current rinse = 130 gal/hr
Tank volume = 250 gal
Dump frequency = 5 days

Hot Dip Seal: ~1/4 g/l CrO_3, no rinse
Tank volume = 250 gal
Dump frequency = 5 days

Total flow to acid-alkali stream = 25,130 l/day (6640 gal/day).

The generalization, comments, and assumptions used for the 38-employee model plant also apply for the smaller 16-employee plating shop.

Calculations Related to Cleaning, Acid-Dips, and Other Processing Baths that are Periodically Dumped

The alkaline cleaner compositions are the same as those given for the 38-employee plant.

Calculations for Line 1

Alkali soak cleaner in dragout and dump stream:

	kg/day	lb/day
NaOH	2.86	6.32
Na_2CO_3	1.81	4.00
Na_2SiO_3	2.03	4.48
$Na_3PO_4 \cdot 12H_2O$	1.05	2.32

Electrolytic cleaner:

	kg/day	lb/day
NaOH	2.39	5.28
Na_2CO_3	0.87	1.92
Na_2SiO_3	2.72	6.00
$Na_3PO_4 \cdot 12H_2O$	0.69	1.52

Sulfuric acid pickle:

Unreacted H_2SO_4 in the dragout and dump stream = 7.01 kg/day
= 15.44 lb/day

The quantity of metals in the dragout and dump stream are

Fe = 410.4 g/day = 0.904 lb/day

Brass = 202.4 g/day = 141.6 g/day = 0.312 lb/day of copper
= 60.7 g/day = 0.136 lb/day of zinc.

Sulfuric acid dip:

Quantity of H_2SO_4 in the dragout and dump stream = 12.16 kg/day
= 26.80 lb/day.

Chemicals lost in the dragout from plating baths:

(a) Cu(CN)-plating

Cu(CN)	1.464 kg/day = 3.224 lb/day
NaCN	2.040 kg/day = 4.512 lb/day
NaOH	1.464 kg/day = 0.320 lb/day
Na_2CO_3	0.534 kg/day = 1.288 lb/day

(b) Ni-plating

$NiSO_4 \cdot 6H_2O$	11.680 kg/day = 25.76 lb/day
$NiCl_2 \cdot 6H_2O$	1.680 kg/day = 3,712 lb/day
H_3BO_3	1.400 kg/day = 3.096 lb/day

(c) Cr-plating

CrO_3	12.600 kg/day = 27.84 lb/day
H_2SO_4	0.126 kg/day = 0.280 lb/day

(Total quantity of CrO_3 needed [15% on workpiece]
= 14.50 kg/day = 32 lb/day)

TABLE C-2. ALKALIS IN DRAGOUTS AND DUMP STREAMS FROM CLEANERS

Lines	NaOH		Na_2CO_3		Na_2SiO_3		$Na_3PO_4 \cdot 12H_2O$	
	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
1	2.86 2.39	6.32 5.28	1.81 0.87	4.00 1.92	2.03 2.72	4.48 6.00	1.05 0.69	2.32 1.52
2	1.05 0.65	2.32 1.44	0.69 0.25	1.52 0.56	0.76 0.76	1.68 1.68	0.40 0.18	0.88 0.40
3	2.07 0.69	4.56 1.52	1.30 -	2.88 -	1.49 -	3.28 -	0.76 -	1.68 -
4	2.39 0.29	5.28 5.04	1.52 -	3.36 -	1.70 -	3.76 -	0.91 -	2.00 -
5	0.80 0.76	1.76 1.68	0.51 -	1.12 -	0.58 -	1.28 -	0.29 -	0.64 -
6	0.72	1.60	0.47	1.04	0.54	1.20	0.29	0.64
Total	16.67	36.80	7.42	16.40	10.58	23.36	4.57	10.08

TABLE C-3. ACIDS AND DISSOLVED METALS IN ACID-ALKALI STREAM FROM DUMPS AND DRAGOUTS, kg/day

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Total 1-6
H_2SO_4	6.99+12.14	2.21+4.67	-	-	15.22	-	41.23
H_3BO_3	1.41	0.54	-	-	-	-	1.95
HCl	-	-	2.65	6.70	-	5.65	15.00
HNO_3	-	-	4.53	-	1.96	-	6.49
H_2SO_4	-	-	-	-	3.84	0.25	4.09
Fe	0.410	0.145	0.517	-	-	1.09	2.15_5
Cu	0.141	0.054	-	-	0.33	-	0.52_5
Zn	0.062	0.022	-	-	-	0.54	0.62_4
Al	-	-	-	-	0.20	-	0.20
Ni	3.19	1.20	-	-	0.011	-	4.40_1
Mn	-	-	-	-	0.065	-	0.06_5

TABLE C-4. ACIDS AND DISSOLVED METALS IN ACID-ALKALI STREAM FROM DUMPS AND DRAGOUTS, lb/day

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Total, 1-6
H_2SO_4	15.44 + 26.80	4.88 + 10.32	--	--	33.60	--	91.04
H_3BO_2	3.12	1.20	--	--	--	--	4.32
HC_1	--	--	5.84	14.80	--	12.48	33.12
HNO_3	--	--	10.00	--	4.32	--	14.72
H_2SO_4	--	--	--	--	8.48	0.56	9.04
Fe	9.04	0.32	1.12	--	--	2.40	4.74_4
Cu	0.312	0.12	--	--	0.72	--	1.15_2
Zn	0.136	0.048	--	--	--	1.20	1.38_4
Al	--	--	--	--	0.44	--	0.44
Ni	7.04	2.64	--	--	0.024	--	9.70_4
Mn	--	--	--	--	0.144	--	0.14_4

Cyanide Destruction

Line 1: Cu(CN)-plating

CN = 425.1 + 1085.9 = 1511 g/day = 3.336 lb/day

Line 2: Cu(CN)-plating

CN = 158.2 + 404.4 = 562.6 g/day = 1.240 lb/day

Line 3: Zn(CN)-plating

CN = 2728 g/day = 6.00 lb/day

Line 4: Cd(CN)-plating

CN = 1760 g/day = 3.92 lb/day

Total CN, 1-4 = 6.562 kg/day = 14.48 lb/day

Total rinse flow, 1-4 = (800 + 320) + 1680 + 920 = 5320 gal/day
Cu + Zn + Cd = 20,135 l/day

The quantity of metals in the CN-streams are:

Cu = 1037 + 387 = 1424 g/day = 3.12 lb/day
Zn = 2285 g/day = 5.04 lb/day
Cd = 830 g/day = 1.44 lb/day

Quantity of Cl_2 required = 49.35 kg/day = 108.8 lb/day
Quantity of caustic soda required = 67.04 kg/day = 148 lb/day = 25.20 gal/day of 50% NaOH or
Quantity of lime required = 61.97 kg/day = 136.8 lb/day.

Reduction of Hexavalent Chromium

Chromium plating:

Line 1: Cr = 6840 g/day = 15.12 lb/day
Line 2: Cr = 2552 g/day = 5.60 lb/day
Total Cr, lines 1 and 2 = 9392 g/day = 20.72 lb/day
Total rinse flow, lines 1 and 2 = 2240 + 840 = 3080 gal/day
= 11,660 l/day

Chromating lines:

Line 3: Cr = 233.0 g/day = 0.512 lb/day in the dragout and dump
520 gal/day rinse + 24 gal/day dump = 544 gal/day
= 2060 l/day containing 174.0 g/day = 0.384 lb/day of zinc

Line 4: Cr = 196 g/day = 0.432 lb/day in the dragout and dump
320 gal/day rinse + 20 gal/day dump = 340 gal/day
= 1290 l/day containing 254 g/day = 0.56 lb/day of cadmium

Line 6: Cr = 12.32 g/day = 0.0272 lb/day

Total chromium, lines 3, 4, and 6 = 441.0 g/day = 0.976 lb/day

Total rinse flow, lines 3, 4, and 6 = 926 gal/day = 3545 l/day

Total chromium, lines 1-6 = 9832 g/day = 21.68 lb/day

Total rinse flow, lines 1-6 = 4016 gal/day = 15,200 l/day

Quantity of SO_2 required = 20.68 kg/day = 45.6 lb/day

Quantity of Zn present = 0.18 kg/day = 0.40 lb/day

Quantity of Cd present = 0.25 kg/day = 0.56 lb/day.

Acid-Alkali Stream

Neutralization:

(a) HNO_3 neutralized with 5.58 kg (12.32 lb) Na_2CO_3
Na_2CO_3 remaining = 1.85 kg (4.08 lb)

(b) HCl neutralized with 1.85 kg (4.08 lb) Na_2CO_3 and 12.33 kg (27.2 lb) NaOH
NaOH remaining = 4.35 kg (9.60 lb)

(c) H_2BO_3 neutralized with 1.27 kg (2.80 lb) NaOH
NaOH remaining = 3.08 kg (6.80 lb)

(d) Neutralization of H_3PO_4 with 3.08 kg (6.80 lb) NaOH and 1.92 kg (4.24 lb) of NaOH added to the stream

(e) Neutralization of H_2SO_4 requires an additional 33.8 kg (74.6 lb) of NaOH

Total NaOH to be added to neutralize the acid-alkali stream excluding metal hydroxide precipitation is 35.73 kg/day (78.9 lb/day). The equivalent quantity of lime required would be 35.63 kg/day (78.6 lb/day).

Rinse Water Flow and pH Adjustments

$$\left.\begin{array}{l}\text{Acid-alkali stream} = 29{,}280\text{ gal/day}\\ \left.\begin{array}{l}\text{Combined CN-streams} = 3720\text{ gal/day}\\ \text{Combined Cr-streams} = 3920\text{ gal/day}\end{array}\right\}\ 7640\text{ gal/day}\end{array}\right\}\ \begin{array}{l}36{,}920\text{ gal/day}\\ = 13{,}975\text{ l/day.}\end{array}$$

Allowing 5 percent water added in the treatment chemicals, total flow = 38,760 gal/day = 146,710 l/day.

To raise the pH from 5.0 to 8.5 for the combined CN and Cr streams requires 0.013 kg/day (0.028 lb/day) of NaOH.

To raise the pH from 6.0 to 8.5 for the acid-alkali stream requires 0.048 kg/day (0.106 lb/day) of NaOH.

The Use of Lime Instead of Caustic Soda in the Treatment Plant

Neutralization of residual H_3PO_4 requires 1.56 kg/day (3.44 lb/day) of $Ca(OH)_2$

Neutralization of H_2SO_4 requires 34.07 kg/day (75.12 lb/day) $Ca(OH)_2$

$CaSO_4$ formed = 57.40 kg/day (126.6 lb/day).

Contributions of Various Streams to Metal Hydroxide Sludges

CN stream:

	kg/day	lb/day
$Cu(OH)_2$	2.18	4.80
$Zn(OH)_2$	3.48	7.68
$Cd(OH)_2$	0.87	1.92

Cr stream:

$Cr(OH)_3$ 19.34 kg/day (42.64 lb/day) requiring
26.34 kg/day (58.08 lb/day) NaOH

$Zn(OH)_2$ 0.29 kg/day (0.64 lb/day) requiring
0.22 kg/day (0.48 lb/day) NaOH

$Cd(OH)_2$ 0.33 kg/day (0.72 lb/day) requiring
0.18 kg/day (0.40 lb/day) NaOH

Acid-alkali stream:

$Fe(OH)_2$ 3.48 kg/day (7.68 lb/day) requiring
3.08 kg/day (6.80 lb/day) NaOH

$Cu(OH)_2$	0.80 kg/day (1.76 lb/day) requiring 0.65 kg/day (1.44 lb/day) NaOH
$Zn(OH)_2$	0.94 kg/day (2.08 lb/day) requiring 0.76 kg/day (1.68 lb/day) NaOH
$Ni(OH)_2$	6.93 kg/day (15.28 lb/day) requiring 5.99 kg/day (13.20 lb/day) NaOH
$Al(OH)_3$	4.61 kg/day (10.16 lb/day) requiring 3.74 kg/day (8.24 lb/day) NaOH
$Mn(OH)_3$	0.11 kg/day (0.24 lb/day) requiring 0.11 kg/day (0.24 lb/day) NaOH
Totals	16.87 kg/day (37.20 lb/day) requiring 14.33 kg/day (31.60 lb/day) NaOH

Combined streams:

$Fe(OH)_2$	3.48 kg/day (7.68 lb/day) requiring 3.08 kg/day (6.80 lb/day) NaOH
$Cu(OH)_2$	2.98 kg/day (6.56 lb/day) requiring 0.65 kg/day (1.44 lb/day) NaOH
$Zn(OH)_2$	4.72 kg/day (10.40 lb/day) requiring 0.98 kg/day (2.16 lb/day) NaOH
$Ni(OH)_2$	6.93 kg/day (15.28 lb/day) requiring 5.99 kg/day (13.20 lb/day) NaOH
$Al(OH)_3$	4.61 kg/day (10.16 lb/day) requiring 3.74 kg/day (8.24 lb/day) NaOH
$Mn(OH)_3$	0.11 kg/day (0.24 lb/day) requiring 0.11 kg/day (0.24 lb/day) NaOH
$Cr(OH)_3$	19.34 kg/day (42.64 lb/day) requiring 26.34 kg/day (58.08 lb/day) NaOH
$Cd(OH)_2$	1.20 kg/day (2.64 lb/day) requiring 0.18 kg/day (0.40 lb/day) NaOH
Totals	43.36 kg/day (95.60 lb/day) requiring 41.07 kg/day (90.56 lb/day) NaOH

Allowing a 10 percent excess of NaOH, the total quantity required is 45.17 kg/day (99.60 lb/day, or 15.68 gal/day of 50 percent NaOH) solution. The equivalent quantity of lime required is 41.83 kg/day (92.24 lb/day).

TABLE C-5. QUANTITY OF METAL HYDROZIDES IN SLUDGE AND EFFLUENT

Metal Hydroxide	Total Quantity, kg/day	Total Quantity, lb/day	Quantity in Effluent, kg/day	Quantity in Effluent, lb/day	Quantity in Sludge, kg/day	Quantity in Sludge, lb/day
$Fe(OH)_2$	3.48	7.68	0.236	0.520	3.24	7.16
$Cu(OH)_2$	2.98	6.56	0.112	0.248	2.86_8	6.31_2
$Zn(OH)_2$	4.72	10.40	0.112	0.248	4.60_8	10.15_2
$Ni(OH)_2$	6.93	15.28	0.116	0.256	6.81_4	15.02_4
$Al(OH)_3$	4.61	10.16	0.424	0.936	4.18_6	9.22_4
$Mn(OH)_3$	0.11	0.24	0.120	0.264	0	0
$Cr(OH)_3$	19.34	42.64	0.145	0.320	19.19_5	42.32
$Cd(OH)_2$	1.20	2.64	0.094	0.208	1.10_6	2.40
Total	43.36	95.60	1.361	3,000	41.99_9	92.62_4

Flocculant Consumption

146,710 l x 0.040 g/l = 5868 g/day = 12.96 lb/day.

Quantity of Sludge Produced

41.98 + 13.10 + 5.88 = 60.95 kg/day
(92.56 + 28.88 + 12.96 = 134.4 lb/day) (using NaOH)
60.95 + 5.88 = 66.83 kg/day (155.92 lb/day) using $Ca(OH)_2$
Clarifier underflow containing 2 percent solids produces
3046 l/day = 805 gal/day of sludge (NaOH) or
3534 l/day = 934 gal/day of sludge ($Ca(OH)_2$)
Centrifuge sludge to 20 percent solids content produces
305.8 l/day = 80.8 gal/day of sludge cake (NaOH) or
354.3 l/day = 93.6 gal/day of sludge cake ($Ca(OH)_2$).

Anode Consumption

Lines 1 and 2: (a) Copper plating = 7.432 kg/day = 16.40 lb/day
(b) Nickel plating = 59.44 kg/day = 131.2 lb/day
Line 3: Zinc plating = 17.632 kg/day = 38.96 lb/day
Line 4: Cadmium plating = 12.288 kg/day = 27.12 lb/day

Bright Dip Consumption

H_3PO_4 = 25.65 kg/day = 56.56 lb/day
HNO_3 = 1.16 kg/day = 2.56 lb/day
Quantity of acid needed for bright dip

The quantity of spent bright dip hauled away consists of
21.77 kg/day = 48.00 lb/day H_3PO_4
and = 51.17 l/day = 13.52 gal/day.
0.98 kg/day = 2.16 lb/day HNO_3

TABLE C-6. CAUSTIC SODA OR LIME CONSUMPTION

Operation	NaOH		$Ca(OH)_2$	
	kg/day	lb/day	kg/day	lb/day
CN-destruction	67.04	148.0	62.08	100.8
Cr-metal precipitation	29.36	64.88	27.28	60.08
Neutralization of acid-alkali stream	35.76	78.88	33.12	78.50
pH-adjustment to 8.5 of acid-alkali stream	0.048	0.106	0.045	0.098
pH-adjustment to 8.5 of combined CN-Cr streams	0.053	0.028	0.012	0.026
Acid-alkali stream metal precipitation	15.84	34.80	14.56	32.24
Total consumption	148.0	326.7	137.0	302.5

Chlorine: 49.28 kg/day or 108.8 lb/day

Sulfur dioxide: 20.64 kg/day or 45.6 lb/day

Flocculant: 5.84 kg/day or 12.96 lb/day

TABLE C-7. MATERIALS CONSUMPTION IN ELECTROPLATING OPERATIONS

Material	Consumption,	
	kg/day	lb/day
Alkaline cleaners	40.96	90.48
NaOH	16.64	36.80
Na_2CO_3	7.44	16.40
Na_2SiO_3	10.56	23.36
$Na_3PO_4 \cdot 12H\ O$	4.56	10.08
Surfactant	1.76	3.84
NaOH	9.20	20.24
Na_2CO_3	2.56	5.60
NaCN	11.20	24.80
$Na_2Cr_2O_7 \cdot 2H_2O$	1.36	2.96
$NiSO_4 \cdot 6H_2O$	16.08	35.52
$NiCl_2 \cdot 6H_2O$	2.32	5.12
$NiC_2H_3O_2$	0.16	0.40
$H_3PO_4 \cdot Zn_3(PO_4)_2$	7.92	17.52
CrO_3	19.92	44.40
CdO	0.72	1.68
$Na_2SnO_3 \cdot 3H_2O$	5.52	12.16
H_3BO_3	1.92	4.32
HCl	15.04	33.12
HNO_3	6.64	14.72
H_3PO_4	2.64	9.04
H_2SO_4	41.28	91.04

Option 1: Centrifuged sludge disposal (20 percent solids content)
Centrifuge size = 6.43 l/min = 1.7 gal/min (NaOH)
= 7.57 l/min = 2.0 gal/min (CaOH)

Cost for a unit having a capacity of 2.5 gal/min is $7,000

Hauling costs: $20.24/day (NaOH)
$23.44/day (CaOH)

Option 2: Lagoon sludge disposal (6 percent solids content)

Volume of sludge = 1015 l/day (268 gal/day)(NaOH)
= 1180 l/day (311 gal/day)($Ca(OH)_2$)

Lagoon size: Holding capacity 30 days

Volume of underflow to lagoon =

106,000 l = 28,000 gal (3,745 cu ft)

20 percent oversize = 4,500 cu ft

Lagoon size = 30 ft x 25 ft x 6 ft, plus

10-ft-wide border = 50 ft x 45 ft x 6 ft

requiring an area of 2,250 ft^2 (0.05 acre)

Land cost: Rural $ 415
Urban $2,065

Excavation and site preparation: $350

Plastic liner installation: $450

Total lagoon costs: Rural $1,215
Urban $2,865

Hauling costs: $32.16/day (NaOH)
$37.36/day ($Ca(OH)_2$)

APPENDIX D

MODEL PLANT C (87 EMPLOYEES)

APPENDIX D

MODEL PLANT C (87 EMPLOYEES)

The data presented in this section were calculated following the criteria set up in Appendix B for the medium-size, 38-employee, model plant. Only the plant operations and the area processed for each line have been changed (Table D-1). The operations described on pages D-5 through D-8 are in addition to or different from the operations of the 38-employee plant.

TABLE D-1. PLANT OPERATIONS

Line or Operation	Assumed Production Rate, m^2/day		Processing Rate, m^2/day		Rinse Water Allowed, l/day		Employees
	m^2/day	ft^2/day	m^2/day	ft^2/day	l/day	gal/day	Rack, Unrack, Plating, etc.
(1) Automatic rack (3 lines) Cu(CN)-Ni-Cr	1680	18,080	5600	60,264	448,000	118,360	21
(2) Manual rack (3 lines) Cu(CN)-Ni-Cr	480	5,168	1660	17.216	128,000	33,840	9
(3) Automatic rack Zn(CN) + chromating	800	8,608	1600	17,216	128,000	33,840	5
(4) Automatic barrel (2 lines) Zn(CN) + chromating	960	10,328	1928	20,664	153,600	40,600	6
(5) Manual barrel, combined 1/2 Cd(CN) + chromating 1/2 Sn-Cu(CN)	320	3,440	480	5,168	38,400	10,160	2
(6) Manual rack Hard Cr	160	1,720	160	1,720	12,800	3,400	2
(7) Manual rack, Al-Anodizing (+ bright dip + Ni-acetate seal)	1200	12,912	3600	38,744	288,000	76,080	12
(8) Automatic barrel Zn-phospating	400	4,304	400	4,304	32,000	8,480	2
(9) Manual electroless Ni	160	1,720	160	1,720	12,800	3,400	2
(10) Automatic rack Pb-Sn-alloy (BF_4^-)	800	8,608	1600	17,216	128,000	33,840	7

TABLE D-1. (Continued)

Line or Operation	Assumed Production Rate, m^2/day	Assumed Production Rate, ft^2/day	Processing Rate, m^2/day	Processing Rate, ft^2/day	Rinse Water Allowed, l/day	Rinse Water Allowed, gal/day	Employees Rack, Unrack, Plating, etc.
Combined Lines	6960	74,904	17,120	184,240	1,369,000	361,840	68
Other Employees:							
Supervision plating							3
Waste treatment							2
Lab analysis							3
Rack-repair-stripping							2
Maintenance							2
Miscellaneous							2
Clerical							3
Management							2
Subtotal							19
Total Plant							87

Assumptions

Dragout rate
rack lines = 12.22 l/100 m^2 (3.0 gal/1000 ft^2)
barrel lines = 20.37 l/100 m^2 (5.0 gal/1000 ft^2)

Rinsing efficiency = 70 percent

Allowable dissolved solids in rinse = 750 mg/l from cleaners, acids, etc.
= 37 mg/l from metal deposition solution
= 15 mg/l from chromium plating solution

Line 1 - Automatic rack Cu(CN)-Ni-Cr
Three identical plating machines, each producing 560 m^2/day
The plating sequence is identical to that of the shop with 38 employees: 1 line plating steel, 1 line plating brass, 1 line plating zinc die castings (p. C-5).

Line 2 - Manual rack Cu(CN)-Ni-Cr with the same applications as Line 1.

Line 3 - Automatic rack Zn(CN) + chromating same as 38-employee plant.

Line 4 - Automatic barrel Zn(CN) + chromating 2 identical plating machines, each producing 480 m^2/day, with a plating sequence identical to the one used in the 38-employee plant.

Line 5 - Manual barrel Cd(Cr) + chromating and Sn-Cd(CN). The line is similar to the one used in the 38-employee plant, except a Sn-Cd-alloy bath is added which uses the same cleaners and rinses.

Line 6 - Manual rack hard Cr. Same as the one used in the 38-employee plant, but with two chromium plating tanks of identical size producing twice the amount.

Line 7 - Manual rack, Al-anodizing. Changes identical to those in Line 6.

Line 8 - Automatic barrel Zn-phosphating. Same as Line 8 of the 38-employee plant.

Line 9 - Manual electroless Ni. Same as Line 9 of the 38-employee plant.

Line 10 - Automatic rack. Pb-Sn-alloy fluoborate bath.

Processing Sequence for Plating Cu(CN)-Ni-Cr on Zinc Die Castings, 560 m^2/day (6024 ft^2/day)
Dragout 69.64 l/day = 184 gal/day

Vibratory finishing	Wastes from vibratory finishing are included in the wastes from the plant operations other than electroplating.
Electrolytic anodic clean	8 oz/gal, single rinse 2120 gal/day Tank volume 1000 gal Dump frequency 15 days
Sulfuric acid dip	1/2% H_2SO_4 = 5 g/l(0.042 lb/gal) 2-tank counter current rinse - 480 gal/day Tank volume 500 gal Dump frequency 5 days
Cu(CN) - strike (0.05 mil thick)	Cu(CN) 3.5 oz/gal (Cu = 2.5 oz/gal) NaCN 4.6 oz/gal (CN = 2.44 oz/gal) Na_2CO_3 4.0 oz/gal Rochelle salt 6.0 oz/gal 2-tank counter current rinse 1600 gal/day
Sulfuric acid dip	1% H_2SO_4 - 10 g/l (0.084 lb/gal) single rinse 770 gal/day Tank volume 500 gal Dump frequency 5 days
Cu-Plate	$Cu_2 P_2O_7 \cdot 3H_2O$ 46 oz/gal (345 g/l) (Cu-3.0 oz/gal) KOH 2.4 oz/gal NH_4OH (29%) 1 oz/gal (8 g/l) 2-tank countercurrent rinse 2560 gal/day
Ni-Plate	as before 2160 gal/day
Cr-Plate	as before 3960 gal/day

		l/day	gal/day
Total flow	=	51,480	13,600
Acid-alkali-stream	=	30,430	8,040
CN-stream	=	6,060	1,600
Cr-stream	=	15,000	3,960

Processing Sequence for Line 2, Plating on Zinc Die Castings = 160 m^2/day = 1720 ft^2/day

Drag out = 19.68 l/day = 5.20 gal/day

Vibratory finishing	
Electrolytic anodic clean	8 oz/gal, single rinse 600 gal/day Tank volume = 300 gal Dump frequency = 20 days
Sulfuric acid dip	1/2% H_2SO_4, 2-tank counter current rinse 480 gal/day Tank volume = 200 gal Dump frequency = 5 days
Cu(CN)-strike	Composition same as Line 1, (zinc die castings) 2-tank counter current rinse 480 gal/day
Sulfuric acid dip	1% H_2SO_4, single rinse 720 gal/day Tank volume = 200 gal Dump frequency = 5 days
Cu-Plate	As Line 1 2-tank counter current rinse 520 gal/day
Ni-Plate	As before 640 gal/day
Cr-Plate	As before 1,120 gal/day

		l/day	gal/day
Total flow	=	17,260	4,560
Acid-alkali-stream	=	11,200	2,960
CN-stream	=	1,820	480
Cr-stream	=	4,240	1,120

Line 5

		l/day	gal/day
Total water flow	=	31,500	8,320
Acid-alkali stream	=	24,230	6,400
CN-stream	=	6,060*	1,600
Cr-stream	=	1,210	320

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* 3480 l/day = 970 gal/day for cadmium plating losing the same bath constituents as before, and 5600 l/day = 1480 gal/day for Sn-Cu-plating.

Sn-Cu-Plate	CuCN	28.5 g/l (3.8 oz/gal)
	$K_2SnO_3 \cdot 3H_2O$	35.25 g/l (4.7 oz/gal)
	KCN	62.3 g/l (8.3 oz/gal)
	KOH	9.8 g/l (1.3 oz/gal)
	$KNaC_4H_4O_6 \cdot 4H_2O$	4.5 g/l (6.0 oz/gal)

Total dissolved solids = 110,300 ppm

$$\text{Water use} = \frac{110,300}{37} \times \frac{8.8}{0.7} = 680 \text{ gal/day} = 2,580 \text{ 1/day}$$

where 8.8 is the drag out in gal/day and 0.7 is the rinse factor.

Line 6

		1/day	gal/day
Drag out	=	20.29	5.36
Total water flow	=	21,500	5,680
Acid-alkali	=	16,960	4,400
Cr-stream	=	4,540	1,200

Line 7

Drag out	=	147	38.72
Total water flow	=	109,920	29,040
Acid-alkali stream	=	109,920	29,040

Line 10

Automatic rack Pb-Sn, 800 m^2/day (8,608 ft^2/day)
Plating steel, drag out 96.9 1/day = 25.6 gal/day

Electrolytic clean	8 oz/gal, single rinse = 11,200 1/day (2,960 gal/day) Tank volume = 500 gal Dump frequency = 15 days
Hydrochloric acid dip	20 vol.% (83%) single rinse = 15,140 1/day = 4,000 gal/day Tank volume = 250 gal Dump frequency = 20 days
Ni-strike (0.001 mil)	$NiCl_2 \cdot 6H_2O$ = 240 g/1 (32 oz/gal) HCl = 55 g/1 Total dissolved solids = 185,900 ppm 2-tank counter flow rinse = 9,690 1/day = 2,560 gal/day
Pb-Sn-plate (93-7)	Sn 6 g/1 Pb 88 g/1 HBF_4 150 g/1 H_3BO_3 40 g/1 2-tank counter flow rinse = 12,110 1/day = 3,200 gal/day Total flow = 48,150 1/day = 12,720 gal/day

Alkaline Soak Cleaner Consumption

25% in sludge = 79.44 kg/day (255.4 lb/day)
75% to react with acids = 59.64 kg/day (131.5 lb/day)

Electrolytic Cleaner Consumption 60.96 kg/day (134.6 lb/day)

25% in sludge = 15.27 kg/day (33.68 lb/day)
75% to react with acids = 45.75 kg/day
(101.9 lb/day)

NaOH Consumption 25.04 kg/day (55.28 lb/day)

to react with acids

Chemicals from Cleaners Available for Reaction

37.06 kg/day + 25.07 kg/day = 62.13 kg/day

NaOH = 81.72 lb/day + 55.28 lb/day =
= 137.0 lb/day
Na_2CO_3 = 19.10 kg/day (42.12 lb/day)
Na_2SiO_3 = 33.23 kg/day (73.26 lb/day)
$Na_3PO_4 \cdot 12H_2O$ = 11.78 kg/day (25.98 lb/day)
Surfactant = emulsified

Drag Outs From Plating Tanks

(a) Cu-Ni-Cr-Plating

	Line 1		Line 2		Total	
	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
$NiSO_4 \cdot 6H_2O$	62.47	137.8	17.85	39.36	80.32	177.14
$NiCl_2 \cdot 6H_2O$	8.99	19.82	2.57	5.67	11.56	25.50
Ni					25.28	55.74
H_3BO_3	7.49	16.51	2.14	4.72	9.63	21.23
CuCN	25.21	55.60	2.01	4.44	9.05	19.96
Cu					6.42	14.15
NaCN	9.69	21.37	2.770	6.11	12.46	27.48
NaOH	0.52	1.15	0.15	0.33	0.67	1.48
Na_2CO_3	4.18	9.22	1.20	2.64	5.38	11.86
Rochelle Salt	3.14	6.92	0.90	1.98	4.03	8.90
CrO_3	51.74	114.1	14.29	32.62	66.53	146.7
Cr					34.60	76.29
H_2SO_4	0.44	0.96	0.12	0.27	0.56	1.23
$Cu_2P_2O_7 \cdot 3H_2O$	24.05	53.04	6.88	15.17	30.93	68.21
Cu					11.07	24.42
KOH	1.26	2.77	0.36	0.79	1.61	3.56
NH_4OH	0.56	1.23	0.160	0.35	0.72	1.58
CN					9.25	20.40

(b) Zn-Plating

Zn	3.88	8.55	7.76	17.11	11.64	25.66
NaOH	8.73	19.25	17.46	38.50	26.19	57.74
NaCN	8.73	19.25	17.46	38.50	26.19	57.74
CN	4.64	10.22	4.64	10.22	9.27	20.44
$Na_2Cr_2O_7 \cdot 2H_2O$	1.45	3.21	2.90	6.42	4.36	9.62
HNO_3	0.73	1.60	1.46	3.20	2.18	4.80
Zn (dissolved)	0.29	0.65	0.58	1.30	0.88	1.94
Cr	0.51	1.12	1.02	2.24	1.52	3.36

(c) Cd-Plating

	kg/day	lb/day
Cd	0.664	1.464
NaCN	3.349	7.384
NaOH	0.475	1.048
Na_2CO_3	1.752	3.864
CN	1.78	3.92
$Na_2Cr_2O_7 \cdot 2H_2O$	0.501	1.104
Cr	0.174	0.384
HNO_3	0.087	0.192
Cd(dissolved)	0.25	0.56

Sn-Cu-Plating

	kg/day	lb/day
CuCN	0.951	2.096
Cu	0.689	1.520
$K_2SNO_3 \cdot 3H_2O$	1.175	2.592
Sn	0.468	1.032
KCN	2.075	4.576
KOH	0.327	0.720
Rochelle Salt	1.502	3.312
CN	1.923	4.240
Sn (dissolved)	0.11	0.24
Al (dissolved)	0.15	0.32

(d) Hard-chromium

CrO_3	6.75	14.89
Cr	3.51	7.74
H_2SO_4	0.08	0.17

(e) Anodizing

Ni-acetate	1.45	3.21
Ni	0.34	0.76

(f) Zinc-phosphating - all in dump streams

(g) Electroless Ni

$NiSO_4 \cdot 7H_2O$	0.59	1.30
Ni	0.12	0.27
$NaH_2PO_2 \cdot H_2O$	0.20	0.44
$NaC_2H_3O_2$	0.20	0.44

(h) Pb-Sn-plating

$NiCl_2 \cdot 6H_2O$	23.29	51.36
Ni	5.75	12.68
HCl	5.33	11.76
Sn	0.58	1.28
Pb	8.54	18.82
HBF_4	14.55	32.08
H_3BO_3	3.88	8.56

TABLE D-2M. ALKALINE SOAK CLEANERS IN DRAGOUT AND DUMP STREAMS, kg/day

	Line 1	2	3	4	5	6	7	8	9	10	Total
NaOH	9.53	2.86	(1.42)	(2.29) 7.15	(0.36)	-	(21.37) 6.35	0.76	1.20	-	(25.07) 27.86
Na_2CO_3	5.99	1.81	-	4.50	-	-	3.99	0.47	0.76	-	17.52
Na_2SiO_3	6.82	2.03	-	5.12	-	-	4.54	0.54	0.83	-	19.70
$Na_3PO_4 \cdot 12H_2O$	3.27	0.98	-	2.47	-	-	2.18	0.25	0.40	-	9.54
Surfactant	1.63	0.49	-	1.31	-	-	1.09	0.15	0.22	-	4.90
Total	27.24	7.97	-	20.55	-	-	18.15	2.17	3.41	-	79.52

TABLE D-3M. ELECTROLYTIC CLEANERS IN DRAGOUT AND DUMP STREAMS, kg/day

	Line 1	2	3	4	5	6	7	8	9	10	Total
NaOH	11.90	2.68	2.00	-	2.39	2.39	-	-	-	2.00	23.36
Na_2CO_3	4.43	0.98	0.73	-	0.87	0.22	-	-	-	0.73	7.96
Na_2SiO_4	13.61	3.08	2.25	-	2.72	0.69	-	-	-	2.25	24.60
$Na_3PO_4 \cdot 12H_2O$	3.37	0.76	0.58	-	0.69	0.18	-	-	-	0.58	6.16
Surfactant	0.22	0.15	0.11	-	0.15	0.04	-	-	-	0.11	0.78
Total	33.53	7.66	5.67	-	6.82	1.72	-	-	-	5.67	61.07

TABLE D-2EU. ALKALINE SOAK CLEANERS IN DRAGOUT AND DUMP STREAMS, kg/day

	Line 1	2	3	4	5	6	7	8	9	10	Total
NaOH	21.04	6.32	(3.12)	(5.04) 15.76	(0.80)	-	(47.12) 14.00	1.68	2.64	-	(55.28) 61.44
Na_2CO_3	13.20	4.00	-	9.92	-	-	8.80	1.04	1.68	-	38.64
Na_2SiO_3	15.04	4.48	-	11.28	-	-	10.00	1.20	1.84	-	43.44
$Na_3PO_4 \cdot 12H_2O$	7.20	2.16	-	5.44	-	-	4.80	0.56	0.88	-	21.04
Surfactant	3.60	1.08	-	2.88	-	-	2.40	0.32	0.48	-	10.80
Total	60.08	17.60	-	45.28	-	-	40.00	4.80	7.52	-	175.36

TABLE D-3EU. ELECTROLYTIC CLEANERS IN DRAGOUT AND DUMP STREAMS, kg/day

	Line 1	2	3	4	5	6	7	8	9	10	Total
NaOH	26.24	5.92	4.40	-	5.28	5.28	-	-	-	4.40	47.58
Na_2CO_3	9.76	2.16	1.60	-	1.92	0.48	-	-	-	1.60	7.52
Na_2SiO_4	30.00	6.80	4.96	-	6.00	1.52	-	-	-	4.96	54.24
$Na_3PO_4 \cdot 12H_2O$	7.44	1.68	1.28	-	1.52	0.40	-	-	-	1.28	13.60
Surfactant	0.48	0.32	0.24	-	0.32	0.08	-	-	-	0.24	1.68
Total	73.92	16.88	12.48	-	15.04	3.76	-	-	-	12.48	134.56

TABLE D-4M. ACIDS IN DRAG OUT AND DUMP STREAM, kg/day

Acids	Line 1	2	3	4	5	6	7	8	9	10	Total
H_2SO_4	23.33	8.56	-	-	-	30.77	211.15	-	-	-	273.81
	40.45	20.39	-	-	-	-	-	-	-	-	60.84
	2.25	0.94	-	-	-	-	-	-	-	-	3.19
	4.46	1.92	-	-	-	-	-	-	-	-	6.38
HCl	-	-	14.95	32.65	15.78	-	-	7.07	12.01	11.94	94.40
HNO_3	-	-	-	-	-	-	22.06	-	-	-	22.06
H_3PO_4	-	-	-	-	-	-	29.89	-	-	-	29.89
Ni-acetate	-	-	-	-	-	-	6.06	-	-	-	6.06
$H_3PO_4 \cdot Zn_2(PO_4)_2$	-	-	-	-	-	-	-	2.65	-	-	2.65
CrO_3	-	-	-	-	-	-	-	0.04	-	-	0.04

H_2SO_4 to react with Fe = 0.15(11.66 + 4.28 + 30.77) = 7.01 kg/day dissolving 3.980 kg/day of Fe

H_2SO_4 to react with Cu/Zn(70/30) = 0.15(11.66 + 4.28) = 2.39 kg/day dissolving 1.09 kg/day of Cu and 0.47 kg/day of Zn

HCl to react with Fe = 0.15(14.95 + 32.65 + 15.78 + 7.07 + 12.01 + 11.94) = 14.16 kg/day dissolving 10.97 kg/day of Fe

$$\left.\begin{array}{l}\text{H}_2\text{SO}_4\text{ to react with Al} = 14.16\text{ kg/day}\\ \text{H}_3\text{PO}_4\text{ to react with Al} = 3.31\text{ kg/day}\end{array}\right\}\text{ dissolving 16.76 kg/day of Al}$$

Total Fe = 3.980 + 14.16 = 18.14 kg/day
Total Cu = 1.09 + 0.23 = 1.32 kg/day
Total Zn = 0.47 + 0.54 = 1.01 kg/day
Total Al = 16.76 kg/day

TABLE D-4EU. ACIDS IN DRAG OUT AND DUMP STREAMS, lb/day

Acids	Line 1	2	3	4	5	6	7	8	9	10	Total
H_2SO_4	51.44	18.88	-	-	-	67.84	465.6	-	-	-	603.8
	89.20	44.96	-	-	-	-	-	-	-	-	134.2
	4.96	2.08	-	-	-	-	-	-	-	-	7.04
	9.84	4.24	-	-	-	-	-	-	-	-	14.08
HCl	-	-	32.96	72.00	34.80	-	-	15.60	26.48	26.32	208.2
HNO_3	-	-	-	-	-	-	48.64	-	-	-	48.64
H_3PO_4	-	-	-	-	-	-	65.92	-	-	-	65.92
Ni-acetate	-	-	-	-	-	-	13.36	-	-	-	13.36
H_3PO_4 - $Zn_2(PO_4)_2$	-	-	-	-	-	-	-	5.84	-	-	5.84
CrO_3	-	-	-	-	-	-	-	0.08	-	-	0.08

H_2SO_4 to react with Fe = 0.15(25.72 + 9.44 + 67.84) = 15.45 lb dissolving 8.776 lb of Fe per day

H_2SO_4 to react with Cu/Zn (70/30) = 0.15(25.72 + 9.44) = 5.28 lb/day dissolving

$$3.44 \left< \begin{array}{l} 2.40 \text{ lb/day of Cu} \\ 1.04 \text{ lb/day of Zn} \end{array} \right.$$

HCl to react with Fe = 0.15(32.96 + 72.00 + 34.80 + 26.48 + 15.60 + 26.32) = 31.224 lb/day, dissolving 24.200 lb/day of Fe

$$\left. \begin{array}{l} H_2SO_4 \text{ to react with Al} = 31.224 \text{ lb/day} \\ H_3PO_4 \text{ to react with Al} = 0.15(48.64) = 7.296 \text{ lb/day} \end{array} \right\} 36.96 \text{ lb/day Al}$$

Total Fe = 8.776 + 31.224 = 40.00 lb/day
Total Cu = 2.40 + 0.512 = 2.912 lb/day
Total Zn = 1.04 + 1.20 = 2.24 lb/day
Total Al = 36.96 lb/day

TABLE D-5M. CHEMICALS FROM PLATING LINES GOING TO WASTE TREATMENT, kg/day

Item	Line 1	2	3	4	5	6	7	8	9	10	Total
$NiSO_4 \cdot 6H_2O$	62.47	17.85	-	-	-	-	-	None	-	-	80.32
$NiSO_4 \cdot 7H_2O$	-	-	-	-	-	-	-	None	0.58	-	0.58
$NiCl_2 \cdot 6H_2O$	9.00	2.58	-	-	-	-	-	None	-	23.29	34.87
Ni-acetate	-	-	-	-	-	-	1.45	None	-	-	1.45
Ni	25.29		-	- -	-	-	0.72	None	0.11	5.77	31.89
H_3BO_3	7.47	2.14	-	-	-	-	-	None	-	3.88	13.49
CuCN	7.04	2.03	-	-	0.94	-	-	None	-	-	10.01
$Cu_2P_2O_7 \cdot 3H_2O$	24.05	6.89	-	-	-	-	-	None	-	-	30.94
Cu		6.42+11.07	-	-	0.69+0.15	-	-	None	-	-	18.33
NaCN	9.69	2.76	8.74	17.45	3.34	-	-	None	-	-	41.98
NaOH	0.51	0.15	8.74	17.45	0.47	-	-	None	-	-	27.32
Na_2CO_3	4.17	1.20	-	-	1.74	-	-	None	-	-	7.11
Rochelle Salt	3.16	0.91	-	-	1.49	-	-	None	-	-	5.56
CrO_3	51.74	14.80	-	-	-	6.75	-	None	-	-	73.29
$Na_2Cr_2O_7 \cdot 2H_2O$	-	-	1.45	2.90	0.51	-	-	None	-	-	4.86
Cr	34.61		0.51	1.02	0.18	3.52	-	None	-	-	39.84
H_2SO_4	0.44	0.11	-	-	-	0.07	-	None	-	-	0.62
KOH	1.27	0.36	-	-	0.33	-	-	None	-	-	1.96
NH_4OH	0.54	0.15	-	-	-	-	-	None	-	-	0.69
Zn	-	-	3.88+0.29	7.76+0.58	-	-	-	None	-	-	12.51
HNO_3	-	-	0.73	1.45	0.07	-	-	None	-	-	2.28
Cd	-	-	-	-	0.65+0.25	-	-	None	-	-	0.90

TABLE D-5M. (Continued)

Item	Line 1	2	3	4	5	6	7	8	9	10	Total
KCN	-	-	-	-	2.07	-	-	None	-	-	2.07
$K_2SnO_3 \cdot 3H_2O$	-	-	-	-	1.16	-	-	None	-	-	1.16
Sn	-	-	-	-	0.47+0.11	-	-	None	-	0.58	1.16
Pb	-	-	-	-	-	-	-	-	-	8.53	8.53
CN	9.27		4.64	4.64	1.78+1.09	-	-	None	0.22	-	21.64
$NaH_2PO_2 \cdot 2HO$	-	-	-	-	-	-	-	-	0.22	-	0.22
$NaC_2H_3O_2$	-	-	-	-	-	-	-	-	0.22	-	0.22
HCl	-	-	-	-	-	-	-	-	-	5.33	5.33
HBF_4	-	-	-	-	-	-	-	-	-	14.55	14.55

TABLE D-5EU. CHEMICALS FROM PLATING LINES GOING TO WASTE TREATMENT, lb/day

Item	Line 1	2	3	4	5	6	7	8	9	10	Total
$NiSO_4 \cdot 6H_2O$	127.76	39.36	-	-	-	-	-	None	-	-	177.12
$NiSO_4 \cdot 7H_2O$	-	-	-	-	-	-	-	None	1.28	-	1.28
$NiCl_2 \cdot 6H_2O$	19.84	5.68	-	-	-	-	-	None	-	51.36	76.88
Ni-acetate	-	-	-	-	-	-	3.20	None	-	-	3.20
Ni	55.76		-	-	-	-	1.60	None	0.24	12.72	69.52
H_3BO_3	16.48	4.72	-	-	-	-	-	None	-	8.56	29.76
CuCN	15.52	4.48	-	-	2.08	-	-	None	-	-	22.08
$Cu_2P_2O_7 \cdot 3H_2O$	53.04	15.20	-	-	-	-	-	None	-	-	68.24
Cu		14.15+24.40	-		1.52+0.32	-	-	None	-	-	40.40
NaCN	21.36	6.08	19.28	38.48	7.36	-	-	None	-	-	92.56
NaOH	1.12	0.32	19.28	38.48	1.04	-	-	None	-	-	60.24
Na_2CO_3	9.20	2.64	-	-	3.84	-	-	None	-	-	15.68
Rochelle Salt	6.96	2.00	-	-	3.28	-	-	None	-	-	12.24
CrO_3	114.08	32.64	-	-	-	14.88	-	None	-	-	161.60
$Na_2Cr_2O_7 \cdot 2H_2O$	-	-	3.20	6.40	1.12	-	-	None	-	-	10.72
Cr	76.32		1.12	2.24	0.40	7.76	-	None	-	-	87.84
H_2SO_4	0.96	0.24	-	-	-	0.16	-	None	-	-	1.36
KOH	2.80	0.80	-	-	0.72	-	-	None	-	-	4.32
NH_4OH	1.20	0.32	-	-	-	-	-	None	-	-	1.52
Zn	-	-	8.56+0.64	17.12+1.28	-	-	-	None	-	-	27.60
HNO_3	-	-	1.60	3.20	0.16	-	-	None	-	-	4.96
Cd	-	-	-	-	1.44 + 0.56	-	-	None	-	-	2.00

TABLE D-5EU. (Continued)

Item	Line 1	2	3	4	5	6	7	8	9	10	Total
KCN	-	-	-	-	4.56	-	-	None	-	-	4.56
$K_2SnO_3 \cdot 3H_2O$	-	-	-	-	2.56	-	-	None	-	-	2.56
Sn	-	-	-	-	1.04 + 0.24	-	-	None	-	1.28	2.56
Pb	-	-	-	-	-	-	-	-	-	18.80	18.80
CN	20.40		10.24	10.24	3.92 + 2.40	-	-	-	0.48	-	44.80
$NaH_2PO_2 \cdot 2HO$	-	-	-	-	-	-	-	-	0.48	-	0.48
$NaC_2H_3O_2$	-	-	-	-	-	-	-	-	0.48	-	0.48
HCl	-	-	-	-	-	-	-	-	-	11.76	11.76
HBF_4	-	-	-	-	-	-	-	-	-	32.08	32.03

TABLE D-6. METAL HYDROXIDE PRECIPITATION

	Metals in Acid Waste		Metals in Plating Solutions		Total Metal		Metal in Sludge*		Sludge Me(OH)	
	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
Cu	1.31	2.80	18.32	40.40	19.63	43.28	19.30	42.56	29.60	65.36
Ni	-	-	31.52	69.52	31.53	69.52	31.20	68.80	49.28	108.80
Cr	-	-	39.84	87.84	39.84	87.84	39.51	87.12	78.00	72.24
Zn	1.02	2.24	12.52	27.60	13.53	29.84	13.21	29.12	19.92	44.40
Sn	-	-	1.16	2.56	1.16	2.56	0.83	1.84	0.72	1.60
Cd	-	-	0.91	2.00	0.91	2.00	0.67	1.48	0.72	1.68
Pb	-	-	8.57	18.90	8.57	18.90	8.20	18.08	9.12	20.24
Fe	18.14	40.00	-	-	18.14	40.00	17.49	38.56	28.08	61.08
Al	16.76	36.96	-	-	16.76	36.96	16.11	35.52	46.40	102.40
Totals	37.22	82.08	112.79	248.72	75.55	166.60	146.43	322.88	261.84	578.40

* Corrected for metal lost in effluent stream.

TABLE D-7. WASTE STREAMS FROM EACH LINE TO TREATMENT PLANT

Total Waste Flow	Acid-Alkali		Chromium		Cyanide		Total	
	1/day	gal/day	1/day	gal/day	1/day	gal/day	1/day	gal/day
Line 1	119,455	31,560	44,965	11,880	16,955	4,480	181,375	47,920
2	36,640	9,680	12,720	3,360	5,150	1,360	54,510	14,400
3	31,795	8,400	3,330	880	10,750	2,840	45,875	12,120
4	63,590	16,800	6,660	1,760	21,500	5,680	91,750	24,240
5	24,225	6,400	1,210	320	6,055	1,600	31,490	8,320
6	16,955	4,480	3,480	920	-	-	20,435	5,400
7	109,915	29,040	-	-	-	-	109,915	29,040
8	25,130	6,640	-	-	-	-	25,130	6,640
9	24,525	6,480	-	-	-	-	24,525	6,480
10	48,145	12,720	-	-	-	-	48,145	12,720
Total Flow/day	500,375	132,200	72,365	19,120	60,410	15,960	633,150	167,280

Total water use - 633,150 1/day 167,280 gal/day
Add 5% with

TABLE D-8. QUANTITY OF METALS LOST WITH EFFLUENT AS METAL HYDROXIDE AND QUANTITY OF HYDROXIDE USED FOR METAL PRECIPITATION

	Amount of Metal in Effluent,		Hydroxide Equivalent Leaving in Effluent,		Amount of NaOH required,	
	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
Cu	0.330	0.728	0.508	1.120	25.94	57.20
Ni	0.330	0.728	0.522	1.152	42.38	93.44
Cr	0.330	0.728	0.653	1.440	105.79	233.28
Zn	0.330	0.728	0.497	1.096	16.00	35.28
Sn	0.330	0.728	0.468*	1.032*	-	-
Cd	0.330	0.728	0.428	0.944	0.40	0.88
Pb	0.330	0.728	0.385	0.848	3.16	6.96
Fe	0.668	1.472	1.074	2.368	25.00	55.12
Al	0.668	1.472	1.926	4.248	37.66	83.04
					256.32	565.20

10% excess NaOH = 281.97 kg/day = 621.76 lb/day

* Precipitated as $SnO_2 \cdot H_2O$

Deductions for NaOH used in CN-destruction (p 18) = 23.47 kg/day
= 51.76 lb/day

NaOH required = 281.97 - 23.47 = 258.50 kg/day (570.0 lb/day)

$Ca(OH)_2$ equivalent = 239.36 kg/day = 528.5 lb/day

Cyanide Destruction

	Lines 1 & 2		Lines 3 & 4		Line 5		Total		NaOH Required	
	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day	kg/day	lb/day
CuCN	9.05	19.96	-	-	0.95	2.10	9.82	21.66	-	-
NaCN	12.46	27.48	26.19	57.74	-	-	38.65	85.22	-	-
CN	9.25	20.40	9.27	20.44	2.87	6.33	21.39	47.17	-	-
KCN	-	-	-	-	2.08	4.58	2.08	4.58	-	-
Cu	6.42	14.15	-	-	0.71	1.56	7.13	15.71	8.92	19.68
Zn	-	-	11.64	25.66	-	-	11.64	25.66	14.08	31.04
Cd	-	-	-	-	0.66	1.46	0.66	1.46	0.47	1.04
Sn	-	-	-	-	0.47	1.03	0.45	1.00	-	-
										51.76

6.82 kg Cl_2 are required for each kg of CN
10% excess = 7.50 kg/kg of CN
18.49 x 7.50 = 138.68 kg/day of Cl_2
40.27 x 7.50 = 353.6 lb/day of Cl_2

9.23 kg NaOH are required for each kg of CN
10% excess = 10.15 kg
21.39 x 10.15 = 217.1 kg/day of NaOH
47.17 x 10.15 = 478.8 lb/day of NaOH

The Ca(OH) equivalent = 201.1 kg/day = 443.4 lb/day

Hexavalent Chromium Reduction

1.86 kg of SO_2 are required per kg of Cr^{6+}
10% excess = 2.04 kg

Total Cr^{6+} in stream = 41.13 kg/day = 90.70 lb/day
Quantity of SO_2 required = 41.13 x 2.04 = 83.9 kg/day
= 90.70 x 2.04 = 185.0 lb/day

Acid-Alkali-Stream Neutralization

(a) Neutralization of HNO_3 with Na_2CO_3

25.18 kg (55.52 lb) of Na_2CO_3 available
22.06 kg (48.64 lb) of HNO_3 present
(22.06)(0.84) = 18.54 kg Na_2CO_3 used up
Quantity of Na_2CO_3 left = 6.64 kg/day = 14.64 lb/day

(b) Neutralization of HCl with Na_2CO_3, NaOH, KOH, and NH_4OH

Quantity of NaOH present = 62.15 kg/day = 137.04 lb/day
Quantity of Na_2CO_3 available = 6.64 kg/day = 14.64 lb/day
Quantity of HCl present = 80.25 kg/day = 176.96 lb/day

1.83 kg Na_2CO_3 will neutralize 1.26 kg HCl

Quantity of HCl still present = 75.68 kg/day = 166.8 lb/day

62.15 kg of NaOH will neutralize 56.49 kg HCl

Quantity of HCl still present = 19.19 kg/day = 42.32 lb/day
KOH present = 1.96 kg/day = 4.32 lb/day
which will neutralize 1.23 kg (2.72 lb HCl)
Quantity of HCl still present = 17.96 kg/day = 39.6 lb/day
NH_4OH present = 0.69 kg/day = 1.52 lb/day

0.69 kg/day of NH_4OH will neutralize 0.62 kg of HCl

HCl left = 17.34 kg/day = 38.24 lb/day

(c) NaOH required to neutralize 17.34 kg of HCl = 19.08 kg/day
= 42.08 lb/day
NaOH required to neutralize 13.50 kg/day (29.76 lb/day) of H_3BO_3
= 8.78 kg/day = 19.36 lb/day
NaOH required to neutralize 29.89 kg/day (65.92 lb/day) of H_3PO_4
36.46 kg/day = 80.40 lb/day
NaOH required to neutralize 320.7 kg/day (707.1 lb/day) of H_2SO_4
= 263.0 kg/day = 579.8 lb/day

Total NaOH required = 592 kg/day = 1305 lb/day
10% excess = 651 kg/day = 1436 lb/day
$Ca(OH)_2$ equivalent = 603 kg/day = 1329 lb/day

The quantity of NaOH or $Ca(OH)_2$ required to raise the pH to 8.5 is negligible.

All $CaSO_4$, $Ca_3(PO_4)_2$, and $CaSiO_3$ formed when lime is used for precipitation and neutralization will leave with the effluent as dissolved solids.

Quantity of unreacted $Ca(OH)_2$ (70 percent of 10% excess) is
51.19 kg/day = 112.9 lb/day

Flocculent Dosage

40 ppm of flocculent will be used for clarification

(0.04 g/l)(666,000) = 26.64 kg/day = 58.80 lb/day

Total Quantity of Solids (Dry Weight)

Source of Sludge	Amount kg/day	 lb/day
Cleaner	35.12	77.52
Metal Hydroxides	261.8	578.48
Flocculent	26.64	58.80
Total Sludge	323.56	714.80

When $Ca(OH)_2$ is used the total quantity of sludge = 323.6 + 51.2 = 374.8 kg/day = 826.5 lb/day

Clarifier Under Flow

2% solids = 16,200 l/day = 4,280 gal/day (NaOH)
= 18,775 l/day = 4,960 gal/day ($Ca(OH)_2$)

Centrifuged Sludge

20% solids = 1,620 l/day = 428 gal/day (NaOH)
= 1,880 l/day = 496 gal/day ($Ca(OH)_2$)

Chemicals Required for Waste Treatment

NaOH = 259 + 217 + 651 = 1,127 kg/day = 2,484 lb/day
or $Ca(OH)_2$ = 239 + 201 + 603 = 1,043 kg/day = 2,302 lb/day
Cl_2 = 138.7 kg/day = 160.2 lb/day
SO_2 = 83.9 kg/day = 185 lb/day
Flocculent = 26.64 kg/day = 58.80 lb/day

APPENDIX E

TABLES OF WASTE QUANTITIES OF VARIOUS TYPES GENERATED BY THE ELECTROPLATING AND METAL FINISHING INDUSTRY

APPENDIX E

TABLES OF WASTE QUANTITIES OF VARIOUS TYPES GENERATED BY THE ELECTROPLATING AND METAL FINISHING INDUSTRY

The information on waste quantities developed through model-plant calculation has been tabulated and is included in this Appendix. The tables contained herein include those concerned with total potentially hazardous waste quantities, quantities for each of the four general categories of wastes, and quantities of the hydroxides of specific metals. In all cases, quantities are given by state and by region.

TABLE E-1. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	1,090.88	1,729.03	634.59	3,454.50
Connecticut	1,129.84	1,394.38	1,163.42	3,687.64
Rhode Island	0.00	3,960.03	634.59	4,594.62
New Hampshire	58.44	0.00	0.00	58.44
Maine	38.96	0.00	105.77	144.73
Vermont	38.96	55.78	0.00	94.74
Region I Total	2,357.08	7,139.22	2,538.37	12,034.67
Region II				
New Jersey	1,655.80	1,171.28	634.59	3,461.67
New York	1,909.04	2,509.88	2,221.07	6,639.99
Region II Total	3,564.84	3,681.16	2,855.66	10,101.66
Region III				
Delaware	19.48	0.00	0.00	19.48
Maryland	214.28	111.55	0.00	325.83
Pennsylvania	1,344.12	1,282.83	1,163.42	3,790.37
Virginia	0.00	111.55	105.77	217.32
West Virginia	155.84	223.10	211.53	590.47
Region III Total	1,733.72	1,729.03	1,480.72	4,943.47
Region IV				
Alabama	272.72	334.65	105.77	713.14
Florida	506.48	167.33	105.77	779.58
Georgia	116.88	111.55	317.30	545.73
Kentucky	77.92	278.88	211.53	568.33
Mississippi	136.36	0.00	105.77	242.13
North Carolina	214.28	446.20	211.53	872.01
South Carolina	155.84	55.78	211.53	423.15
Tennessee	155.84	557.75	105.77	819.36
Region IV Total	1,636.32	1,952.14	1,374.97	4,963.43
Region V				
Illinois	2,142.80	2,007.90	2,538.36	6,689.06
Indiana	915.56	725.07	951.88	2,592.52
Michigan	2,396.04	5,633.28	3,490.25	11,519.56
Minnesota	350.64	501.98	423.06	1,275.68
Ohio	2,805.12	2,565.65	2,326.83	7,697.60
Wisconsin	389.60	446.20	634.59	1,470.39
Region V Total	8,999.76	11,880.08	10,364.97	31,244.81

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-1. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	38.96	111.55	105.77	256.28
Louisiana	19.48	55.78	0.00	75.26
New Mexico	97.40	55.78	0.00	153.18
Oklahoma	136.36	55.78	211.53	403.67
Texas	896.08	780.85	846.12	2,523.05
Region VI Total	1,188.28	1,059.74	1,163.42	3,411.44
Region VII				
Iowa	292.20	167.33	423.06	882.58
Kansas	272.72	0.00	740.36	1,013.08
Missouri	584.40	334.65	951.88	1,870.94
Nebraska	58.44	111.55	0.00	169.99
Region VII Total	1,207.76	613.53	2,115.30	3,936.59
Region VIII				
Colorado	272.72	167.33	528.83	968.88
Montana	19.48	0.00	0.00	19.48
North Dakota	0.00	0.00	0.00	0.00
South Dakota	19.48	0.00	0.00	19.48
Utah	116.88	55.78	0.00	172.66
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	428.56	223.11	528.83	1,180.50
Region IX				
Arizona	214.28	223.10	105.77	543.15
California	1,558.40	1,896.35	1,586.48	5,041.23
Hawaii	19.48	0.00	0.00	19.48
Nevada	77.92	0.00	0.00	77.92
Region IX Total	1,870.08	2,119.45	1,692.25	5,681.78
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	58.44	0.00	0.00	58.44
Oregon	194.80	55.78	317.30	567.88
Washington	389.60	223.10	0.00	612.70
Region X Total	642.84	278.88	317.30	1,239.02
Total U. S.	23,629.24	30,676.34	24,431.79	78,737.37

TABLE E-2. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WATER POLLUTION CONTROL SLUDGES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY; (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1975

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region I				
Massachusetts	297.92	379.75	170.10	847.77
Connecticut	308.56	306.25	311.85	926.66
Rhode Island	0.00	869.75	170.10	1,039.85
New Hampshire	15.96	0.00	0.00	15.96
Maine	10.64	0.00	28.35	38.99
Vermont	10.64	12.25	0.00	22.89
Region I Total	643.72	1,568.00	680.40	2,892.12
Region II				
New Jersey	452.20	257.25	170.10	879.55
New York	521.36	551.25	595.35	1,667.96
Region II Total	973.56	808.50	765.45	2,547.51
Region III				
Delaware	5.32	0.00	0.00	5.32
Maryland	58.52	24.50	0.00	83.02
Pennsylvania	367.08	281.75	311.85	960.68
Virginia	0.00	24.50	28.35	52.85
West Virginia	42.56	49.00	56.70	148.26
Region III Total	473.48	379.75	396.90	1,250.13
Region IV				
Alabama	74.48	73.50	28.35	176.33
Florida	138.32	36.75	28.35	203.42
Georgia	31.92	24.50	85.05	141.47
Kentucky	21.28	61.25	56.70	139.23
Mississippi	37.24	0.00	28.35	65.59
North Carolina	58.52	98.00	56.70	213.22
South Carolina	42.56	12.25	56.70	111.51
Tennessee	42.56	122.50	28.35	193.41
Region IV Total	446.88	428.75	368.55	1,244.18
Region V				
Illinois	585.20	441.00	680.40	1,706.60
Indiana	250.04	159.25	255.15	664.44
Michigan	654.36	1,237.25	935.55	2,827.16
Minnesota	95.76	110.25	113.40	319.41
Ohio	766.08	563.50	623.70	1,953.28
Wisconsin	106.40	98.00	170.10	374.50
Region V Total	2,457.84	2,609.25	2,778.30	7,845.39

* These dry weights can be converted to wet weights by applying a factor of 20 for a sludge containing 5 percent solids.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-2. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	10.64	24.50	28.35	63.49
Louisiana	5.32	12.25	0.00	17.57
New Mexico	26.60	12.25	0.00	38.85
Oklahoma	37.24	12.25	56.70	106.19
Texas	244.72	171.50	226.80	643.02
Region VI Total	324.52	232.75	311.85	869.12
Region VII				
Iowa	79.80	36.75	113.40	229.95
Kansas	74.48	0.00	198.45	272.93
Missouri	159.60	73.50	255.15	488.25
Nebraska	15.96	24.50	0.00	40.46
Region VII Total	329.84	134.75	567.00	1,031.59
Region VIII				
Colorado	74.48	36.75	141.75	252.98
Montana	5.32	0.00	0.00	5.32
North Dakota	0.00	0.00	0.00	0.00
South Dakota	5.32	0.00	0.00	5.32
Utah	31.92	12.25	0.00	44.17
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	117.04	49.00	141.75	307.79
Region IX				
Arizona	58.52	49.00	28.35	135.87
California	425.60	416.50	425.25	1,267.35
Hawaii	5.32	0.00	0.00	5.32
Nevada	21.28	0.00	0.00	21.28
Region IX Total	510.72	465.50	453.60	1,429.82
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	15.96	0.00	0.00	15.96
Oregon	53.20	12.25	85.05	150.50
Washington	106.40	49.00	0.00	155.40
Region X Total	175.56	61.25	85.05	321.86
Total U. S.	6,453.16	6,737.50	6,548.85	19,739.51

TABLE E-3. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS PROCESS WASTES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY; (JOB SHOPS), METRIC TONS; DRY WEIGHT*; 1975

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	678.16	784.61	351.48	1,814.25
Connecticut	702.38	632.75	644.38	1,979.51
Rhode Island	0.00	1,797.01	351.48	2,148.49
New Hampshire	36.33	0.00	0.00	36.33
Maine	24.22	0.00	58.58	82.80
Vermont	24.22	25.31	0.00	49.53
Region I Total	1,465.31	3,239.68	1,405.92	6,110.91
Region II				
New Jersey	1,029.35	531.51	351.48	1,912.34
New York	1,186.78	1,138.95	1,230.18	3,555.91
Region II Total	2,216.13	1,670.46	1,581.66	5,468.25
Region III				
Delaware	12.11	0.00	0.00	12.11
Maryland	133.21	50.62	0.00	183.83
Pennsylvania	835.59	582.13	644.38	2,062.10
Virginia	0.00	50.62	58.58	109.20
West Virginia	96.88	101.24	117.16	315.28
Region III Total	1,077.79	784.61	820.12	2,682.52
Region IV				
Alabama	169.54	151.86	58.58	379.98
Florida	314.86	75.93	58.58	449.37
Georgia	72.66	50.62	175.74	299.02
Kentucky	48.44	126.55	117.16	292.15
Mississippi	84.77	0.00	58.58	143.35
North Carolina	133.21	202.48	117.16	452.85
South Carolina	96.88	25.31	117.16	239.35
Tennessee	96.88	253.10	58.58	408.56
Region IV Total	1,017.24	885.85	761.54	2,664.63
Region V				
Illinois	1,332.10	911.16	1,405.92	3,649.18
Indiana	569.17	329.03	527.22	1,425.42
Michigan	1,489.53	2,556.31	1,933.14	5,978.98
Minnesota	217.98	227.79	234.32	680.09
Ohio	1,743.84	1,164.26	1,288.76	4,196.86
Wisconsin	242.20	202.48	351.48	796.16
Region V Total	5,594.82	5,391.03	5,740.84	16,726.69

* Dry Weight = Wet Weight

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-3. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	24.22	50.62	58.58	133.42
Louisiana	12.11	25.31	0.00	37.42
New Mexico	60.55	25.31	0.00	85.86
Oklahoma	84.77	25.31	117.16	227.24
Texas	557.06	354.34	468.64	1,380.04
Region VI Total	738.71	480.89	644.38	1,863.98
Region VII				
Iowa	181.65	75.93	234.32	491.90
Kansas	169.54	0.00	410.06	579.60
Missouri	363.30	151.86	527.22	1,042.38
Nebraska	36.33	50.62	0.00	86.95
Region VII Total	750.82	278.41	1,171.60	2,200.83
Region VIII				
Colorado	169.54	75.93	292.90	538.37
Montana	12.11	0.00	0.00	12.11
North Dakota	0.00	0.00	0.00	0.00
South Dakota	12.11	0.00	0.00	12.11
Utah	72.66	25.31	0.00	97.97
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	266.42	101.24	292.90	660.56
Region IX				
Arizona	133.21	101.24	58.58	293.03
California	968.80	860.54	878.70	2,708.04
Hawaii	12.11	0.00	0.00	12.11
Nevada	48.44	0.00	0.00	48.44
Region IX Total	1,162.56	961.78	937.28	3,061.62
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	36.33	0.00	0.00	36.33
Oregon	121.10	25.31	175.74	322.15
Washington	242.20	101.24	0.00	343.44
Region X Total	399.63	126.55	175.74	701.92
Total U. S.	14,689.43	13,920.50	13,531.98	42,141.91

TABLE E-4. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS DEGREASER SLUDGES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1975

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	114.80	111.29	25.26	251.35
Connecticut	118.90	89.75	46.31	254.96
Rhode Island	0.00	254.89	25.26	280.15
New Hampshire	6.15	0.00	0.00	6.15
Maine	4.10	0.00	4.21	8.31
Vermont	4.10	3.59	0.00	7.69
Region I Total	248.05	459.52	101.04	808.61
Region II				
New Jersey	174.25	75.39	25.26	274.90
New York	200.90	161.55	88.41	450.86
Region II Total	375.15	236.94	113.67	725.76
Region III				
Delaware	2.05	0.00	0.00	2.05
Maryland	22.55	7.18	0.00	29.73
Pennsylvania	141.45	82.57	46.31	270.33
Virginia	0.00	7.18	4.21	11.39
West Virginia	16.40	14.36	8.42	39.18
Region III Total	182.45	111.29	58.94	352.68
Region IV				
Alabama	28.70	21.54	4.21	54.45
Florida	53.30	10.77	4.21	68.28
Georgia	12.30	7.18	12.63	32.11
Kentucky	8.20	17.95	8.42	34.57
Mississippi	14.35	0.00	4.21	18.56
North Carolina	22.55	28.72	8.42	59.69
South Carolina	16.40	3.59	8.42	28.41
Tennessee	16.40	35.90	4.21	56.51
Region IV Total	172.20	125.65	54.73	352.58
Region V				
Illinois	225.50	129.24	101.04	455.78
Indiana	96.35	46.67	37.89	180.91
Michigan	252.15	362.59	138.93	753.67
Minnesota	36.90	32.31	16.84	86.05
Ohio	295.20	165.14	92.62	552.96
Wisconsin	41.00	28.72	25.26	94.98
Region V Total	947.10	764.67	412.58	2,124.35

* Dry Weight = Wet Weight.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-4. (Continued)

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region VI				
Arkansas	4.10	7.18	4.21	15.49
Louisiana	2.05	3.59	0.00	5.64
New Mexico	10.25	3.59	0.00	13.84
Oklahoma	14.35	3.59	8.42	26.36
Texas	94.30	50.26	33.68	178.24
Region VI Total	125.05	68.21	46.31	239.57
Region VII				
Iowa	30.75	10.77	16.84	58.36
Kansas	28.70	0.00	29.47	58.17
Missouri	61.50	21.54	37.89	120.93
Nebraska	6.15	7.18	0.00	13.33
Region VII Total	127.10	39.49	84.20	250.79
Region VIII				
Colorado	28.70	10.77	21.05	60.52
Montana	2.05	0.00	0.00	2.05
North Dakota	0.00	0.00	0.00	0.00
South Dakota	2.05	0.00	0.00	2.05
Utah	12.30	3.59	0.00	15.89
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	45.10	14.36	21.05	80.51
Region IX				
Arizona	22.55	14.36	4.21	41.12
California	164.00	122.06	63.15	349.21
Hawaii	2.05	0.00	0.00	2.05
Nevada	8.20	0.00	0.00	8.20
Region IX Total	196.80	136.42	67.36	400.58
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	6.15	0.00	0.00	6.15
Oregon	20.50	3.59	12.63	36.72
Washington	41.00	14.3	0.00	55.36
Region X Total	67.65	17.95	12.63	98.23
Total U. S.	2,486.65	1,974.50	972.51	5,433.66

TABLE E-5. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS ELECTROLESS NICKEL PLATING WASTES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1975

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	453.38	87.75	541.13
Connecticut	0.00	365.63	160.88	526.50
Rhode Island	0.00	1,038.38	87.75	1,126.13
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	14.63	14.63
Vermont	0.00	14.63	0.00	14.63
Region I Total	0.00	1,872.02	351.01	2,223.03
Region II				
New Jersey	0.00	307.13	87.75	394.88
New York	0.00	658.13	307.13	965.25
Region II Total	0.00	965.26	394.88	1,360.13
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	29.25	0.00	29.25
Pennsylvania	0.00	336.38	160.88	497.25
Virginia	0.00	29.25	14.63	43.88
West Virginia	0.00	58.50	29.25	87.75
Region III Total	0.00	453.38	204.76	658.13
Region IV				
Alabama	0.00	87.75	14.63	102.38
Florida	0.00	43.88	14.63	58.50
Georgia	0.00	29.25	43.88	73.13
Kentucky	0.00	73.13	29.25	102.38
Mississippi	0.00	0.00	14.63	14.63
North Carolina	0.00	117.00	29.25	146.25
South Carolina	0.00	14.63	29.25	43.88
Tennessee	0.00	146.25	14.63	160.88
Region IV Total	0.00	511.89	190.15	702.03
Region V				
Illinois	0.00	526.50	351.00	877.50
Indiana	0.00	190.13	131.63	321.75
Michigan	0.00	1,477.13	482.63	1,959.75
Minnesota	0.00	131.63	58.50	190.13
Ohio	0.00	672.75	321.75	994.50
Wisconsin	0.00	117.00	87.75	204.75
Region V Total	0.00	3,115.14	1,433.26	4,548.38

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* These dry weights can be converted to wet weights by applying a factor of two for a sludge containing 50 percent solids after filtration.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-5. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	0.00	29.25	14.63	43.88
Louisiana	0.00	14.63	0.00	14.63
New Mexico	0.00	14.63	0.00	14.63
Oklahoma	0.00	14.63	29.25	43.88
Texas	0.00	204.75	117.00	321.75
Region VI Total	0.00	277.89	160.88	438.77
Region VII				
Iowa	0.00	43.88	58.50	102.38
Kansas	0.00	0.00	102.38	102.38
Missouri	0.00	87.75	131.63	219.38
Nebraska	0.00	29.25	0.00	29.25
Region VII Total	0.00	160.88	292.51	453.39
Region VIII				
Colorado	0.00	43.88	73.13	117.00
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	14.63	0.00	14.63
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	58.51	73.13	131.63
Region IX				
Arizona	0.00	58.50	14.63	73.13
California	0.00	497.25	219.38	716.63
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	555.75	234.01	789.76
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	14.63	43.88	58.50
Washington	0.00	58.50	0.00	58.50
Region X Total	0.00	73.13	43.88	117.00
Total U. S.	0.00	8,043.60	3,378.47	11,422.25

TABLE E-6. TOTAL QUANTITY OF HAZARDOUS METAL HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Total	Iron	Copper	Zinc	Nickel	Aluminum	Chromium	Cadmium	Tin	Lead	Manganese
Region I											
Massachusetts	338.07	43.84	24.60	46.11	57.03	37.33	116.08	6.52	.30	4.14	.12
Connecticut	376.51	47.02	33.70	47.69	67.73	39.84	125.76	6.54	.55	7.59	.09
Rhode Island	415.04	66.25	27.65	62.46	60.55	59.15	130.39	4.88	.30	4.14	.27
New Hampshire	6.09	.52	.48	.80	1.14	.38	2.54	.23	0.00	0.00	0.00
Maine	16.69	1.88	1.97	1.68	3.50	1.57	5.15	.20	.05	.69	0.00
Vermont	8.84	1.15	.57	1.32	1.38	.97	3.24	.21	0.00	0.00	0.00
Region I Total	1,162.24	160.66	90.97	160.06	191.33	139.24	383.16	18.58	1.20	16.56	.48
Region II											
New Jersey	349.04	40.85	28.73	46.03	61.87	33.76	125.22	8.06	.30	4.14	.08
New York	679.84	85.36	61.62	85.51	122.75	72.48	225.07	11.35	1.04	14.49	.17
Region II Total	1,028.88	126.21	90.35	131.54	184.62	106.24	350.29	19.41	1.34	18.63	.25
Region III											
Delaware	2.04	.17	.16	.27	.38	.13	.85	.08	0.00	0.00	0.00
Maryland	31.93	3.52	2.25	4.50	5.44	2.83	12.42	.96	0.00	0.00	.01
Pennsylvania	389.26	47.33	34.95	49.06	70.68	39.78	131.99	7.24	.55	7.59	.09
Virginia	22.21	3.14	2.15	2.71	3.98	2.76	6.54	.18	.05	.69	.01
West Virginia	60.66	7.67	5.58	7.56	11.00	6.53	19.86	.96	.10	1.38	.02
Region III Total	506.10	61.83	45.09	64.10	91.48	52.03	171.66	9.42	.70	9.66	.13
Region IV											
Alabama	69.81	8.79	5.39	9.58	11.80	7.41	24.59	1.49	.05	.69	.02
Florida	79.81	8.47	6.55	10.44	14.51	6.76	30.13	2.20	.05	.69	.01
Georgia	59.64	7.24	6.42	6.61	11.73	6.15	18.53	.73	.15	2.07	.01
Kentucky	57.36	7.78	5.20	7.28	10.10	6.75	18.02	.73	.10	1.38	.02
Mississippi	26.85	2.75	2.77	3.02	5.40	2.20	9.39	.58	.05	.69	0.00
North Carolina	85.94	11.40	7.06	11.50	14.64	9.79	28.59	1.45	.10	1.38	.03
South Carolina	46.30	5.26	4.84	5.22	9.14	4.36	15.23	.77	.10	1.38	0.00
Tennessee	76.80	10.96	5.43	11.11	12.00	9.54	25.68	1.30	.05	.69	.04
Region IV Total	502.51	62.65	43.66	64.76	89.32	52.96	170.16	9.25	.65	8.97	.13
Region V											
Illinois	698.96	84.81	66.26	85.11	129.93	71.45	231.69	11.82	1.19	16.56	.14
Indiana	271.38	32.40	25.64	33.06	50.61	27.16	90.99	4.83	.43	6.21	.05
Michigan	1,150.53	153.09	99.45	149.79	199.91	131.86	374.19	17.45	1.64	22.77	.38
Minnesota	130.19	16.49	11.74	16.44	23.39	14.03	42.97	2.14	.20	2.76	.03
Ohio	790.69	95.70	70.87	99.72	143.65	80.31	269.08	14.92	1.09	15.18	.17
Wisconsin	154.72	19.09	15.12	18.49	29.00	16.20	50.02	2.33	.30	4.14	.03
Region V Total	3,196.47	401.58	289.08	402.61	576.49	341.01	1,058.94	53.49	4.85	67.62	.80

TABLE E-6. (Continued)

Region VI											
Arkansas	26.28	3.49	2.47	3.25	4.74	3.01	8.24	.33	.05	.69	.01
Louisiana	6.82	.98	.41	1.05	1.00	.85	2.39	.14	0.00	0.00	0.00
New Mexico	14.94	1.67	1.05	2.12	2.53	1.35	5.78	.44	0.00	0.00	0.00
Oklahoma	44.26	5.08	4.68	4.95	8.76	4.24	14.38	.69	.10	1.38	0.00
Texas	261.53	31.50	24.07	32.43	48.11	26.44	88.24	4.77	.40	5.52	.05
Region VI Total	353.83	42.72	32.68	43.80	65.14	35.89	119.03	6.37	.55	7.59	.06
Region VII											
Iowa	95.34	11.14	9.76	10.95	18.52	9.32	31.15	1.53	.20	2.76	.01
Kansas	116.83	13.15	13.82	11.78	24.48	10.99	36.02	1.41	.35	4.83	0.00
Missouri	203.31	23.82	21.18	23.04	39.77	19.96	65.76	3.10	.45	6.21	.02
Nebraska	15.68	2.13	.98	2.37	2.39	1.82	5.63	.35	0.00	0.00	.01
Region VI Total	431.16	50.24	45.74	48.14	85.16	42.09	138.56	6.39	1.00	13.80	.04
Region VIII											
Colorado	105.95	12.50	11.26	11.83	20.87	10.52	33.76	1.50	.25	3.45	.01
Montana	2.04	.17	.16	.27	.38	.13	.85	.08	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Dakota	2.04	.17	.16	.27	.38	.13	.85	.08	0.00	0.00	0.00
Utah	16.99	1.85	1.21	2.39	2.91	1.48	6.63	.52	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Region VIII Total	127.02	14.69	12.79	14.76	24.54	12.26	42.09	2.18	.25	3.45	.01
Region IX											
Arizona	54.15	6.66	4.41	7.22	9.41	5.59	18.96	1.14	.05	.69	.02
California	514.83	64.21	46.08	65.20	92.65	54.37	172.12	8.98	.74	10.35	.13
Hawaii	2.04	.17	.16	.27	.38	.13	.85	.08	0.00	0.00	0.00
Nevada	8.12	.70	.64	1.07	1.52	.50	3.39	.30	0.00	0.00	0.00
Region IX Total	579.14	71.74	51.29	73.76	103.96	60.59	195.32	10.50	.79	11.04	.15
Region X											
Alaska	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idaho	6.09	.52	.48	.80	1.14	.38	2.54	.23	0.00	0.00	0.00
Oregon	62.98	7.14	6.81	6.90	12.64	5.93	20.37	.97	.15	2.07	0.00
Washington	59.78	6.69	4.19	8.47	10.11	5.40	23.14	1.76	0.00	0.00	.02
Region X Total	128.85	14.35	11.48	16.17	23.89	11.71	46.05	2.96	.15	2.07	.02
TOTAL U. S.	8,016.20	1,006.67	713.13	1,019.70	1,435.93	854.02	2,675.26	138.55	11.48	159.39	2.07

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-7. TOTAL QUANTITY OF CHROMIUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	47.49	47.89	20.70	116.08
Connecticut	49.18	38.62	37.95	125.76
Rhode Island	0.00	109.69	20.70	130.39
New Hampshire	2.54	0.00	0.00	2.54
Maine	1.70	0.00	3.45	5.15
Vermont	1.70	1.54	0.00	3.24
Region I Total	102.61	197.74	82.80	383.16
Region II				
New Jersey	72.08	32.44	20.70	125.22
New York	83.10	69.52	72.45	225.07
Region II Total	155.18	101.96	93.15	350.29
Region III				
Delaware	.85	0.00	0.00	.85
Maryland	9.33	3.09	0.00	12.42
Pennsylvania	58.51	35.53	37.95	131.99
Virginia	0.00	3.09	3.45	6.54
West Virginia	6.78	6.18	6.90	19.86
Region III Total	75.47	47.89	48.30	171.66
Region IV				
Alabama	11.87	9.27	3.45	24.59
Florida	22.05	4.63	3.45	30.13
Georgia	5.09	3.09	10.35	18.53
Kentucky	3.39	7.72	6.90	18.02
Mississippi	5.94	0.00	3.45	9.39
North Carolina	9.33	12.36	6.90	28.59
South Carolina	6.78	1.54	6.90	15.23
Tennessee	6.78	15.45	3.45	25.68
Region IV Total	71.23	54.06	44.85	170.16
Region V				
Illinois	93.28	55.62	82.80	231.69
Indiana	39.86	20.08	31.05	90.99
Michigan	104.30	156.04	113.84	374.19
Minnesota	15.26	13.90	13.80	42.97
Ohio	122.11	71.07	75.90	269.08
Wisconsin	16.96	12.36	20.70	50.02
Region V Total	391.77	329.07	338.09	1,058.94

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-7. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	1.70	3.09	3.45	8.24
Louisiana	.85	1.54	0.00	2.39
New Mexico	4.24	1.54	0.00	5.78
Oklahoma	5.94	1.54	6.90	14.38
Texas	39.01	21.63	27.60	88.24
Region VI Total	51.74	29.34	37.95	119.03
Region VII				
Iowa	12.72	4.63	13.80	31.15
Kansas	11.87	0.00	24.15	36.02
Missouri	25.44	9.27	31.05	65.76
Nebraska	2.54	3.09	0.00	5.63
Region VII Total	52.57	16.99	69.00	138.56
Region VIII				
Colorado	11.87	4.63	17.25	33.76
Montana	.85	0.00	0.00	.85
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.85	0.00	0.00	.85
Utah	5.09	1.54	0.00	6.63
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	18.66	6.17	17.25	42.09
Region IX				
Arizona	9.33	6.18	3.45	18.96
California	67.84	52.53	51.75	172.12
Hawaii	.85	0.00	0.00	.85
Nevada	3.39	0.00	0.00	3.39
Region IX Total	81.41	58.71	55.20	195.32
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	2.54	0.00	0.00	2.54
Oregon	8.48	1.54	10.35	20.37
Washington	16.96	6.18	0.00	23.14
Region X Total	27.98	7.72	10.35	46.05
Total U. S.	1,028.62	849.65	796.94	2,675.26

TABLE E-8. TOTAL QUANTITY OF NICKEL HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	21.35	19.27	16.40	57.03
Connecticut	22.11	15.54	30.07	67.73
Rhode Island	0.00	44.14	16.40	60.55
New Hampshire	1.14	0.00	0.00	1.14
Maine	.76	0.00	2.73	3.50
Vermont	.76	.62	0.00	1.38
Region I Total	46.12	79.57	65.60	191.33
Region II				
New Jersey	32.40	13.06	16.40	61.87
New York	37.36	27.98	57.41	122.75
Region II Total	69.76	41.04	73.81	184.62
Region III				
Delaware	.38	0.00	0.00	.38
Maryland	4.19	1.24	0.00	5.44
Pennsylvania	26.31	14.30	30.07	70.68
Virginia	0.00	1.24	2.73	3.98
West Virginia	3.05	2.49	5.47	11.00
Region III Total	33.93	19.27	38.27	91.48
Region IV				
Alabama	5.34	3.73	2.73	11.80
Florida	9.91	1.87	2.73	14.51
Georgia	2.29	1.24	8.20	11.73
Kentucky	1.52	3.11	5.47	10.10
Mississippi	2.67	0.00	2.73	5.40
North Carolina	4.19	4.97	5.47	14.64
South Carolina	3.05	.62	5.47	9.14
Tennessee	3.05	6.22	2.73	12.00
Region IV Total	32.02	21.76	35.53	89.32
Region V				
Illinois	41.94	22.38	65.62	129.93
Indiana	17.92	8.08	24.61	50.61
Michigan	46.89	62.79	90.22	199.91
Minnesota	6.86	5.60	10.94	23.39
Ohio	54.90	28.60	60.15	143.65
Wisconsin	7.62	4.97	16.40	29.00
Region V Total	176.13	132.42	267.94	576.49

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-8. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.76	1.24	2.73	4.74
Louisiana	.38	.62	0.00	1.00
New Mexico	1.91	.62	0.00	2.53
Oklahoma	2.67	.62	5.47	8.76
Texas	17.54	8.70	21.87	48.11
Region VI Total	23.26	11.80	30.07	65.14
Region VII				
Iowa	5.72	1.87	10.94	18.52
Kansas	5.34	0.00	19.14	24.48
Missouri	11.44	3.73	24.61	39.77
Nebraska	1.14	1.24	0.00	2.39
Region VII Total	23.64	6.84	54.69	85.16
Region VIII				
Colorado	5.34	1.87	13.67	20.87
Montana	.38	0.00	0.00	.38
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.38	0.00	0.00	.38
Utah	2.29	.62	0.00	2.91
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	8.39	2.49	13.67	24.54
Region IX				
Arizona	4.19	2.49	2.73	9.41
California	30.50	21.14	41.01	92.65
Hawaii	.38	0.00	0.00	.38
Nevada	1.52	0.00	0.00	1.52
Region IX Total	36.59	23.63	43.74	103.96
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.14	0.00	0.00	1.14
Oregon	3.81	.62	8.20	12.64
Washington	7.62	2.49	0.00	10.11
Region X Total	12.57	3.11	8.20	23.89
Total U. S.	462.41	341.93	631.52	1,435.93

TABLE E-9. TOTAL QUANTITY OF ZINC HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975.

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	14.95	24.26	6.89	46.11
Connecticut	15.49	19.57	12.63	47.69
Rhode Island	0.00	55.57	6.89	62.46
New Hampshire	.80	0.00	0.00	.80
Maine	.53	0.00	1.15	1.68
Vermont	.53	.78	0.00	1.32
Region I Total	32.30	100.18	27.56	160.06
Region II				
New Jersey	22.70	16.44	6.89	46.03
New York	26.17	35.22	24.11	85.51
Region II Total	48.87	51.66	31.00	131.54
Region III				
Delaware	.27	0.00	0.00	.27
Maryland	2.94	1.57	0.00	4.50
Pennsylvania	18.43	18.00	12.63	49.06
Virginia	0.00	1.57	1.15	2.71
West Virginia	2.14	3.13	2.30	7.56
Region III Total	23.78	24.27	16.08	64.10
Region IV				
Alabama	3.74	4.70	1.15	9.58
Florida	6.94	2.35	1.15	10.44
Georgia	1.60	1.57	3.44	6.61
Kentucky	1.07	3.91	2.30	7.28
Mississippi	1.87	0.00	1.15	3.02
North Carolina	2.94	6.26	2.30	11.50
South Carolina	2.14	.78	2.30	5.22
Tennessee	2.14	7.83	1.15	11.11
Region IV Total	22.44	27.40	14.94	64.76
Region V				
Illinois	20.38	28.18	27.56	85.11
Indiana	12.55	10.18	10.33	33.06
Michigan	32.85	79.06	37.89	149.79
Minnesota	4.81	7.04	4.59	16.44
Ohio	38.46	36.01	25.26	99.72
Wisconsin	5.34	6.26	6.89	18.49
Region V Total	114.39	166.73	112.52	402.61

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-9. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.53	1.57	1.15	3.25
Louisiana	.27	.78	0.00	1.05
New Mexico	1.34	.78	0.00	2.12
Oklahoma	1.87	.78	2.30	4.95
Texas	12.28	10.96	9.19	32.43
Region VI Total	16.29	14.87	12.64	43.80
Region VII				
Iowa	4.01	2.35	4.59	10.95
Kansas	3.74	0.00	8.04	11.78
Missouri	8.01	4.70	10.33	23.04
Nebraska	.80	1.57	0.00	2.37
Region VII Total	16.56	8.62	22.96	48.14
Region VIII				
Colorado	3.74	2.35	5.74	11.83
Montana	.27	0.00	0.00	.27
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.27	0.00	0.00	.27
Utah	1.60	.78	0.00	2.39
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	5.88	3.13	5.74	14.76
Region IX				
Arizona	2.94	3.13	1.15	7.22
California	21.36	26.61	17.22	65.20
Hawaii	.27	0.00	0.00	.27
Nevada	1.07	0.00	0.00	1.07
Region IX Total	25.64	29.74	18.37	73.76
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.80	0.00	0.00	.80
Oregon	2.67	.78	3.44	6.90
Washington	5.34	3.13	0.00	8.47
Region X Total	8.81	3.91	3.44	16.17
Total U. S.	314.96	430.51	265.25	1,019.70

TABLE E-10. TOTAL QUANTITY OF IRON HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975.

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region I				
Massachusetts	9.74	24.91	9.18	43.84
Connecticut	10.09	20.09	16.84	47.02
Rhode Island	0.00	57.06	9.18	66.25
New Hampshire	.52	0.00	0.00	.52
Maine	.35	0.00	1.53	1.88
Vermont	.35	.80	0.00	1.15
Region I Total	21.05	102.86	36.73	160.66
Region II				
New Jersey	14.79	16.88	9.18	40.85
New York	17.05	36.17	32.14	85.36
Region II Total	31.84	53.05	41.32	126.21
Region III				
Delaware	.17	0.00	0.00	.17
Maryland	1.91	1.61	0.00	3.52
Pennsylvania	12.01	18.48	16.84	47.33
Virginia	0.00	1.61	1.53	3.14
West Virginia	1.39	3.21	3.06	7.67
Region III Total	15.48	24.91	21.43	61.83
Region IV				
Alabama	2.44	4.82	1.53	8.79
Florida	4.52	2.41	1.53	8.47
Georgia	1.04	1.61	4.59	7.24
Kentucky	.70	4.02	3.06	7.78
Mississippi	1.22	0.00	1.53	2.75
North Carolina	1.91	6.43	3.06	11.40
South Carolina	1.39	.80	3.06	5.26
Tennessee	1.39	8.04	1.53	10.96
Region IV Total	14.61	28.13	18.89	62.65
Region V				
Illinois	19.14	28.93	36.74	84.81
Indiana	8.18	10.45	13.78	32.40
Michigan	21.40	81.17	50.51	153.09
Minnesota	3.13	7.23	6.12	16.49
Ohio	25.06	36.97	33.68	95.70
Wisconsin	3.48	6.43	9.18	19.09
Region V Total	80.39	171.18	149.74	401.58

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-10. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.35	1.61	1.53	3.49
Louisiana	.17	.80	0.00	.98
New Mexico	.87	.80	0.00	1.67
Oklahoma	1.22	.80	3.06	5.08
Texas	8.00	11.25	12.25	31.50
Region VI Total	10.61	15.26	16.84	42.72
Region VII				
Iowa	2.61	2.41	6.12	11.14
Kansas	2.44	0.00	10.71	13.15
Missouri	5.22	4.82	13.78	23.82
Nebraska	.52	1.61	0.00	2.13
Region VII Total	10.79	8.84	30.61	50.24
Region VIII				
Colorado	2.44	2.41	7.65	12.50
Montana	.17	0.00	0.00	.17
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.17	0.00	0.00	.17
Utah	1.04	.80	0.00	1.85
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	3.82	3.21	7.65	14.69
Region IX				
Arizona	1.91	3.21	1.53	6.66
California	13.92	27.33	22.96	64.21
Hawaii	.17	0.00	0.00	.17
Nevada	.70	0.00	0.00	.70
Region IX Total	16.70	30.54	24.49	71.74
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.52	0.00	0.00	.52
Oregon	1.74	.80	4.59	7.14
Washington	3.48	3.21	0.00	6.69
Region X Total	5.74	4.01	4.59	14.35
Total U. S.	211.03	441.27	352.29	1,006.67

TABLE E-11. TOTAL QUANTITY OF ALUMINUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region I				
Massachusetts	7.05	22.37	7.91	37.33
Connecticut	7.30	18.04	14.49	39.83
Rhode Island	0.00	51.24	7.91	59.15
New Hampshire	.38	0.00	0.00	.38
Maine	.25	0.00	1.32	1.57
Vermont	.25	.72	0.00	.97
Region I Total	15.23	92.37	31.63	139.23
Region II				
New Jersey	10.70	15.16	7.91	33.77
New York	12.34	32.48	27.67	72.49
Region II Total	23.04	47.64	35.58	106.26
Region III				
Delaware	.13	0.00	0.00	.13
Maryland	1.38	1.44	0.00	2.83
Pennsylvania	8.69	16.60	14.49	39.78
Virginia	0.00	1.44	1.32	2.76
West Virginia	1.01	2.89	2.64	6.53
Region III Total	11.21	22.37	18.45	52.03
Region IV				
Alabama	1.76	4.33	1.32	7.41
Florida	3.27	2.17	1.32	6.76
Georgia	.76	1.44	3.95	6.15
Kentucky	.50	3.61	2.64	6.75
Mississippi	.88	0.00	1.32	2.20
North Carolina	1.38	5.77	2.64	9.79
South Carolina	1.01	.72	2.64	4.36
Tennessee	1.01	7.22	1.32	9.54
Region IV Total	10.57	25.26	17.15	52.96
Region V				
Illinois	13.85	25.98	31.62	71.45
Indiana	5.92	9.38	11.86	27.16
Michigan	15.48	72.89	43.48	131.86
Minnesota	2.27	6.50	5.27	14.03
Ohio	18.13	33.20	28.99	80.31
Wisconsin	2.52	5.77	7.91	16.20
Region V Total	58.17	153.72	129.13	341.01

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-11. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	.25	1.44	1.32	3.01
Louisiana	.13	.72	0.00	.85
New Mexico	.63	.72	0.00	1.35
Oklahoma	.88	.72	2.64	4.24
Texas	5.79	10.10	10.54	26.44
Region VI Total	7.68	13.70	14.50	35.89
Region VII				
Iowa	1.89	2.17	5.27	9.32
Kansas	1.76	0.00	9.22	10.99
Missouri	3.78	4.33	11.86	19.96
Nebraska	.38	1.44	0.00	1.82
Region VII Total	7.81	7.94	26.35	42.09
Region VIII				
Colorado	1.76	2.17	6.59	10.52
Montana	.13	0.00	0.00	.13
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.13	0.00	0.00	.13
Utah	.76	.72	0.00	1.48
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	2.78	2.89	6.59	12.26
Region IX				
Arizona	1.38	2.89	1.32	5.59
California	10.07	24.54	19.76	54.37
Hawaii	.13	0.00	0.00	.13
Nevada	.50	0.00	0.00	.50
Region IX Total	12.08	27.43	21.08	60.59
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.38	0.00	0.00	.38
Oregon	1.26	.72	3.95	5.93
Washington	2.52	2.89	0.00	5.40
Region X Total	4.16	3.61	3.95	11.71
Total U. S.	152.73	396.93	304.41	854.03

TABLE E-12. TOTAL QUANTITY OF COPPER HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS: DRY WEIGHT: 1975

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	8.94	7.74	9.93	26.61
Connecticut	9.25	6.24	18.20	33.69
Rhode Island	0.00	17.72	9.93	27.65
New Hampshire	.48	0.00	0.00	.48
Maine	.32	0.00	1.65	1.97
Vermont	.32	.25	0.00	.57
Region I Total	19.31	31.95	39.71	90.97
Region II				
New Jersey	13.56	5.24	9.93	28.73
New York	15.64	11.23	34.75	61.62
Region II Total	29.20	16.47	44.68	90.35
Region III				
Delaware	.16	0.00	0.00	.16
Maryland	1.76	.50	0.00	2.26
Pennsylvania	11.01	5.74	18.20	34.95
Virginia	0.00	.50	1.65	2.15
West Virginia	1.28	1.00	3.31	5.59
Region III Total	14.21	7.74	23.16	45.11
Region IV				
Alabama	2.23	1.50	1.65	5.38
Florida	4.15	.75	1.65	6.55
Georgia	.96	.50	4.96	6.42
Kentucky	.64	1.25	3.31	5.20
Mississippi	1.12	0.00	1.65	2.77
North Carolina	1.76	2.00	3.31	7.07
South Carolina	1.28	.25	3.31	4.84
Tennessee	1.28	2.50	1.65	5.43
Region IV Total	13.42	8.75	21.49	43.66
Region V				
Illinois	17.55	8.99	39.72	66.26
Indiana	7.50	3.24	14.89	25.63
Michigan	19.63	25.21	54.61	99.45
Minnesota	2.87	2.25	6.62	11.74
Ohio	22.98	11.48	36.41	70.87
Wisconsin	3.19	2.00	9.93	15.12
Region V Total	73.72	53.17	162.18	289.06

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-12. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.32	.50	1.65	2.47
Louisiana	.16	.25	0.00	.41
New Mexico	.80	.25	0.00	1.05
Oklahoma	1.12	.25	3.31	4.68
Texas	7.34	3.49	13.24	24.07
Region VI Total	9.74	4.74	18.20	32.68
Region VII				
Iowa	2.39	.75	6.62	9.76
Kansas	2.23	0.00	11.58	13.82
Missouri	4.79	1.50	14.89	21.18
Nebraska	.48	.50	0.00	.98
Region VII Total	9.89	2.75	33.09	45.73
Region VIII				
Colorado	2.23	.75	8.27	11.25
Montana	.16	0.00	0.00	.16
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.16	0.00	0.00	.16
Utah	.96	.25	0.00	1.21
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	3.51	1.00	8.27	12.78
Region IX				
Arizona	1.76	1.00	1.65	4.41
California	12.77	8.49	24.82	46.08
Hawaii	.16	0.00	0.00	.16
Nevada	.64	0.00	0.00	.64
Region IX Total	15.33	9.48	26.47	51.28
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.48	0.00	0.00	.48
Oregon	1.60	.25	4.96	6.81
Washington	3.19	1.00	0.00	4.19
Region X Total	5.27	1.25	4.96	11.48
Total U. S.	193.60	137.30	382.20	713.11

TABLE E-13. TOTAL QUANTITY OF LEAD HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	0.00	0.00	4.14	4.14
Connecticut	0.00	0.00	7.59	7.59
Rhode Island	0.00	0.00	4.14	4.14
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	.69	.69
Vermont	0.00	0.00	0.00	0.00
Region I Total	0.00	0.00	16.56	16.56
Region II				
New Jersey	0.00	0.00	4.14	4.14
New York	0.00	0.00	14.49	14.49
Region II Total	0.00	0.00	18.63	18.63
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	0.00	0.00
Pennsylvania	0.00	0.00	7.59	7.59
Virginia	0.00	0.00	.69	.69
West Virginia	0.00	0.00	1.38	1.38
Region III Total	0.00	0.00	9.66	9.66
Region IV				
Alabama	0.00	0.00	.69	.69
Florida	0.00	0.00	.69	.69
Georgia	0.00	0.00	2.07	2.07
Kentucky	0.00	0.00	1.38	1.38
Mississippi	0.00	0.00	.69	.69
North Carolina	0.00	0.00	1.38	1.38
South Carolina	0.00	0.00	1.38	1.38
Tennessee	0.00	0.00	.69	.69
Region IV Total	0.00	0.00	8.97	8.97
Region V				
Illinois	0.00	0.00	16.56	16.56
Indiana	0.00	0.00	6.21	6.21
Michigan	0.00	0.00	22.77	22.77
Minnesota	0.00	0.00	2.76	2.76
Ohio	0.00	0.00	15.18	15.18
Wisconsin	0.00	0.00	4.14	4.14
Region V Total	0.00	0.00	67.62	67.62

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-13. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	0.00	.69	.69
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	1.38	1.38
Texas	0.00	0.00	5.52	5.52
Region VI Total	0.00	0.00	7.59	7.59
Region VII				
Iowa	0.00	0.00	2.76	2.76
Kansas	0.00	0.00	4.83	4.83
Missouri	0.00	0.00	6.21	6.21
Nebraska	0.00	0.00	0.00	0.00
Region VII Total	0.00	0.00	13.80	13.80
Region VIII				
Colorado	0.00	0.00	3.45	3.45
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	0.00	3.45	3.45
Region IX				
Arizona	0.00	0.00	.69	.69
California	0.00	0.00	10.35	10.35
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	0.00	11.04	11.04
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	2.07	2.07
Washington	0.00	0.00	0.00	0.00
Region X Total	0.00	0.00	2.07	2.07
Total U. S.	0.00	0.00	159.39	159.39

TABLE E-14. TOTAL QUANTITY OF CADMIUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	4.21	2.00	.31	6.52
Connecticut	4.36	1.61	.56	6.54
Rhode Island	0.00	4.58	.31	4.88
New Hampshire	.23	0.00	0.00	.23
Maine	.15	0.00	.05	.20
Vermont	.15	.06	0.00	.21
Region I Total	9.10	8.25	1.23	18.58
Region II				
New Jersey	6.39	1.35	.31	8.06
New York	7.37	2.90	1.07	11.35
Region II Total	13.76	4.25	1.38	19.39
Region III				
Delaware	.08	0.00	0.00	.08
Maryland	.83	.13	0.00	.96
Pennsylvania	5.19	1.48	.56	7.23
Virginia	0.00	.13	.05	.18
West Virginia	.60	.26	.10	.96
Region III Total	6.70	2.00	.71	9.41
Region IV				
Alabama	1.05	.39	.05	1.49
Florida	1.96	.19	.05	2.20
Georgia	.45	.13	.15	.73
Kentucky	.30	.32	.10	.73
Mississippi	.53	0.00	.05	.58
North Carolina	.83	.52	.10	1.45
South Carolina	.60	.06	.10	.77
Tennessee	.60	.64	.05	1.30
Region IV Total	6.32	2.25	.65	9.22
Region V				
Illinois	8.28	2.32	1.23	11.82
Indiana	3.54	.84	.46	4.83
Michigan	9.25	6.51	1.68	17.45
Minnesota	1.35	.58	.20	2.14
Ohio	10.83	2.97	1.12	14.92
Wisconsin	1.50	.52	.31	2.33
Region V Total	34.75	13.74	5.00	53.49

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-14. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.15	.13	.05	.33
Louisiana	.08	.06	0.00	.14
New Mexico	.38	.06	0.00	.44
Oklahoma	.53	.06	.10	.69
Texas	3.46	.90	.41	4.77
Region VI Total	4.60	1.21	.56	6.38
Region VII				
Iowa	1.13	.19	.20	1.53
Kansas	1.05	0.00	.36	1.41
Missouri	2.26	.39	.46	3.10
Nebraska	.23	.13	0.00	.35
Region VII Total	4.67	.71	1.02	6.40
Region VIII				
Colorado	1.05	.19	.26	1.50
Montana	.08	0.00	0.00	.08
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.08	0.00	0.00	.08
Utah	.45	.06	0.00	.52
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	1.66	.25	.26	2.18
Region IX				
Arizona	.83	.26	.05	1.14
California	6.02	2.19	.77	8.98
Hawaii	.08	0.00	0.00	.08
Nevada	.30	0.00	0.00	.30
Region IX Total	7.23	2.45	.82	10.50
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.23	0.00	0.00	.23
Oregon	.75	.06	.15	.97
Washington	1.50	.26	0.00	1.76
Region X Total	2.48	.32	.15	2.95
Total U. S.	91.26	35.60	11.84	138.50

TABLE E-15. TOTAL QUANTITY OF TIN HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	0.00	0.00	.30	.30
Connecticut	0.00	0.00	.55	.55
Rhode Island	0.00	0.00	.30	.30
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	.05	.05
Vermont	0.00	0.00	0.00	0.00
Region I Total	0,00	0.00	1.20	1.20
Region II				
New Jersey	0.00	0.00	.30	.30
New York	0.00	0.00	1.04	1.04
Region II Total	0.00	0.00	1.34	1.34
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	0.00	0.00
Pennsylvania	0.00	0.00	.55	.55
Virginia	0.00	0.00	.05	.05
West Virginia	0.00	0.00	.10	.10
Region III Total	0.00	0.00	.70	.70
Region IV				
Alabama	0.00	0.00	.05	.05
Florida	0.00	0.00	.05	.05
Georgia	0.00	0.00	.15	.15
Kentucky	0.00	0.00	.10	.10
Mississippi	0.00	0.00	.05	.05
North Carolina	0.00	0.00	.10	.10
South Carolina	0.00	0.00	.10	.10
Tennessee	0.00	0.00	.05	.05
Region IV Total	0.00	0.00	.55	.55
Region V				
Illinois	0.00	0.00	1.19	1.19
Indiana	0.00	0.00	.45	.45
Michigan	0.00	0.00	1.64	1.64
Minnesota	0.00	0.00	.20	.20
Ohio	0.00	0.00	1.09	1.09
Wisconsin	0.00	0.00	.30	.30
Region V Total	0.00	0.00	4.87	4.87

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-15. (Continued)

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region VI				
Arkansas	0.00	0.00	.05	.05
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	.10	.10
Texas	0.00	0.00	.40	.40
Region VI Total	0.00	0.00	.55	.55
Region VII				
Iowa	0.00	0.00	.20	.20
Kansas	0.00	0.00	.35	.35
Missouri	0.00	0.00	.45	.45
Nebraska	0.00	0.00	0.00	0.00
Region VII Total	0.00	0.00	1.00	1.00
Region VIII				
Colorado	0.00	0.00	.25	.25
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	0.00	.25	.25
Region IX				
Arizona	0.00	0.00	.05	.05
California	0.00	0.00	.74	.74
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	0.00	.79	.79
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	.15	.15
Washington	0.00	0.00	0.00	0.00
Region X Total	0.00	0.00	.15	.15
Total U. S.	0.00	0.00	11.40	11.40

TABLE E-16. TOTAL QUANTITY OF MANGANESE HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS) METRIC TONS; DRY WEIGHT; 1975

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	.12	0.00	.12
Connecticut	0.00	.09	0.00	.09
Rhode Island	0.00	.27	0.00	.27
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	0.00	0.00
Vermont	0.00	0.00	0.00	0.00
Region I Total	0.00	.48	0.00	.48
Region II				
New Jersey	0.00	.08	0.00	.08
New York	0.00	.17	0.00	.17
Region II Total	0.00	.25	0.00	.25
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	.01	0.00	.01
Pennsylvania	0.00	.09	0.00	.09
Virginia	0.00	.01	0.00	.01
West Virginia	0.00	.02	0.00	.02
Region III Total	0.00	.13	0.00	.13
Region IV				
Alabama	0.00	.02	0.00	.02
Florida	0.00	.01	0.00	.01
Georgia	0.00	.01	0.00	.01
Kentucky	0.00	.02	0.00	.02
Mississippi	0.00	0.00	0.00	0.00
North Carolina	0.00	.03	0.00	.03
South Carolina	0.00	0.00	0.00	0.00
Tennessee	0.00	.04	0.00	.04
Region IV Total	0.00	.14	0.00	.14
Region V				
Illinois	0.00	.14	0.00	.14
Indiana	0.00	.05	0.00	.05
Michigan	0.00	.38	0.00	.38
Minnesota	0.00	.03	0.00	.03
Ohio	0.00	.17	0.00	.17
Wisconsin	0.00	.03	0.00	.03
Region V Total	0.00	.77	0.00	.77

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-16. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	.01	0.00	.01
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	0.00	0.00
Texas	0.00	.05	0.00	.05
Region VI Total	0.00	.07	0.00	.07
Region VII				
Iowa	0.00	.01	0.00	.01
Kansas	0.00	0.00	0.00	0.00
Missouri	0.00	.02	0.00	.02
Nebraska	0.00	.01	0.00	.01
Region VII Total	0.00	.04	0.00	.04
Region VIII				
Colorado	0.00	.01	0.00	.01
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	.02	0.00	.02
Region IX				
Arizona	0.00	.02	0.00	.02
California	0.00	.13	0.00	.13
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	.14	0.00	.14
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	0.00	0.00
Washington	0.00	.02	0.00	.02
Region X Total	0.00	.02	0.00	.02
Total U. S.	0.00	2.06	0.00	2.06

TABLE E-17. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT: 1977

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	1,644.16	2,434.28	950.49	5,028.93
Connecticut	1,702.88	1,963.13	1,742.57	5,408.58
Rhode Island	0.00	5,575.28	950.49	6,525.77
New Hampshire	88.08	0.00	0.00	88.08
Maine	58.72	0.00	158.42	217.14
Vermont	58.72	78.53	0.00	137.25
Region I Total	3,552.56	10,051.22	3,801.97	17,405.75
Region II				
New Jersey	2,495.60	1,649.03	950.49	5,095.12
New York	2,877.28	3,533.63	3,326.72	9,737.63
Region II Total	5,372.88	5,182.66	4,277.21	14,832.75
Region III				
Delaware	29.36	0.00	0.00	29.36
Maryland	322.96	157.05	0.00	480.01
Pennsylvania	2,025.84	1,806.08	1,742.57	5,574.49
Virginia	0.00	157.05	158.42	315.47
West Virginia	234.88	314.10	316.83	865.81
Region III Total	2,613.04	2,434.28	2,217.82	7,265.14
Region IV				
Alabama	411.04	471.15	158.42	1,040.61
Florida	763.36	235.58	158.42	1,157.36
Georgia	176.16	157.05	475.25	808.46
Kentucky	117.44	392.63	316.83	826.90
Mississippi	205.52	0.00	158.42	363.94
North Carolina	322.96	628.20	316.83	1,267.99
South Carolina	234.88	78.53	316.83	630.24
Tennessee	234.88	785.25	158.42	1,178.55
Region IV Total	2,466.24	2,748.39	2,059.42	7,274.05
Region V				
Illinois	3,229.60	2,826.90	3,801.96	9,858.46
Indiana	1,379.92	1,020.83	1,425.74	3,826.49
Michigan	3,611.28	7,931.03	5,227.70	16,770.01
Minnesota	528.48	706.72	633.66	1,868.86
Ohio	4,227.84	3,612.15	3,485.13	11,325.12
Wisconsin	587.20	628.20	950.49	2,165.89
Region V Total	13,564.32	16,725.83	15,524.68	45,814.83

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-17. (Continued)

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region VI				
Arkansas	58.72	157.05	158.42	374.19
Louisiana	29.36	78.53	0.00	107.89
New Mexico	146.80	78.53	0.00	225.33
Oklahoma	205.52	78.53	316.83	600.88
Texas	1,350.56	1,099.35	1,267.32	3,717.23
Region VI Total	1,790.96	1,491.99	1,742.57	5,025.52
Region VII				
Iowa	440.40	235.58	533.66	1,209.64
Kansas	411.04	0.00	1,108.91	1,519.95
Missouri	880.80	471.15	1,425.74	2,777.69
Nebraska	88.08	157.05	0.00	245.13
Region VII Total	1,820.32	863.78	3,068.31	5,752.41
Region VIII				
Colorado	411.04	235.58	792.08	1,438.70
Montana	29.36	0.00	0.00	29.36
North Dakota	0.00	0.00	0.00	0.00
South Dakota	29.36	0.00	0.00	29.36
Utah	176.16	78.53	0.00	254.69
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	645.92	314.11	792.08	1,752.11
Region IX				
Arizona	322.96	314.10	158.42	795.48
California	2,348.80	2,669.85	2,376.23	7,394.88
Hawaii	29.36	0.00	0.00	29.36
Nevada	117.44	0.00	0.00	117.44
Region IX Total	2,818.56	2,983.95	2,534.65	8,337.16
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	88.08	0.00	0.00	88.08
Oregon	293.60	78.53	475.25	847.38
Washington	587.20	314.10	0.00	901.30
Region X Total	968.88	392.63	475.25	1,836.76
Total U. S.	35,613.68	43,188.84	36,493.96	115,296.48

TABLE E-18. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WATER POLLUTION CONTROL SLUDGES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1977

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	851.20	1,085.00	486.00	2,422.20
Connecticut	881.60	875.00	891.00	2,647.60
Rhode Island	0.00	2,485.00	486.00	2,971.00
New Hampshire	45.60	0.00	0.00	45.60
Maine	30.40	0.00	81.00	111.40
Vermont	30.40	35.00	0.00	65.40
Region I Total	1839.20	4,480.00	1944.00	8,263.20
Region II				
New Jersey	1292.00	735.00	486.00	2,513.00
New York	1489.60	1,575.00	1701.00	4,765.60
Region II Total	2781.60	2,310.00	2187.00	7,278.60
Region III				
Delaware	15.20	0.00	0.00	15.20
Maryland	167.20	70.00	0.00	237.20
Pennsylvania	1048.80	805.00	891.00	2,744.80
Virginia	0.00	70.00	81.00	151.00
West Virginia	121.60	140.00	162.00	423.60
Region III Total	1352.80	1,085.00	1134.00	3,571.80
Region IV				
Alabama	212.80	210.00	81.00	503.80
Florida	395.20	105.00	81.00	581.20
Georgia	91.20	70.00	243.00	404.20
Kentucky	60.80	175.00	162.00	397.80
Mississippi	106.40	0.00	81.00	187.40
North Carolina	167.20	280.00	162.00	609.20
South Carolina	121.60	35.00	162.00	318.60
Tennessee	121.60	350.00	81.00	552.60
Region IV Total	1276.80	1,225.00	1,053.00	3,554.80
Region V				
Illinois	1672.00	1,260.00	1944.00	4,876.00
Indiana	714.40	455.00	729.00	1,898.40
Michigan	1869.60	3,535.00	2673.00	8,077.60
Minnesota	273.60	315.00	324.00	912.60
Ohio	2188.80	1,610.00	1782.00	5,580.80
Wisconsin	304.00	280.00	486.00	1,070.00
Region V Total	7022.40	7,455.00	7938.00	22,415.40

* These dry weights can be converted to wet weights by applying a factor of 5 for a sludge containing 20 percent solids.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-18. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	30.40	70.0	81.0	181.40
Louisiana	15.20	35.0	0.0	50.20
New Mexico	76.00	35.0	0.0	111.00
Oklahoma	106.40	35.0	162.0	303.40
Texas	699.20	490.0	648.0	1,837.20
Region VI Total	927.20	665.0	891.0	2,483.20
Region VII				
Iowa	228.00	105.0	324.0	657.00
Kansas	212.80	0.0	567.0	779.80
Missouri	456.00	210.0	729.0	1,395.00
Nebraska	45.60	70.0	0.0	115.60
Region VII Total	942.40	385.0	1620.0	2,947.40
Region VIII				
Colorado	212.80	105.0	405.0	722.80
Montana	15.20	0.0	0.0	15.20
North Dakota	0.00	0.0	0.0	0.00
South Dakota	15.20	0.0	0.0	15.20
Utah	91.20	35.0	0.0	126.20
Wyoming	0.00	0.0	0.0	0.00
Region VIII Total	334.40	140.0	405.0	879.40
Region IX				
Arizona	167.20	140.0	81.0	388.20
California	1216.00	1,190.0	1215.0	3,621.00
Hawaii	15.20	0.0	0.0	15.20
Nevada	60.80	0.0	0.0	60.80
Region IX Total	1459.20	1,330.0	1296.0	4,085.20
Region X				
Alaska	0.00	0.0	0.0	0.00
Idaho	45.60	0.0	0.0	45.60
Oregon	152.00	35.0	243.0	430.00
Washington	304.00	140.0	0.0	444.00
Region X Total	501.60	175.0	243.0	919.60
Total U. S.	18,437.60	19,250.0	18,711.0	56,398.60

TABLE E-19. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS PROCESS WASTES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1977

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	678.16	784.61	351.48	1,814.25
Connecticut	702.38	632.75	644.38	1,979.51
Rhode Island	0.00	1,797.01	351.48	2,148.49
New Hampshire	36.33	0.00	0.00	36.33
Maine	24.22	0.00	58.58	82.80
Vermont	24.22	25.31	0.00	49.53
Region I Total	1,465.31	3,239.68	1,405.92	6,110.91
Region II				
New Jersey	1,029.35	531.51	351.48	1,912.34
New York	1,186.78	1,138.95	1,230.18	3,555.91
Region II Total	2,216.13	1,670.46	1,581.66	5,468.25
Region III				
Delaware	12.11	0.00	0.00	12.11
Maryland	133.21	50.62	0.00	183.83
Pennsylvania	835.59	582.13	644.38	2,062.10
Virginia	0.00	50.60	58.58	109.18
West Virginia	96.88	101.24	117.16	315.28
Region III Total	1,077.79	784.59	820.12	2,682.50
Region IV				
Alabama	169.54	151.86	58.58	379.98
Florida	314.86	75.93	58.58	449.37
Georgia	72.66	50.62	175.74	299.02
Kentucky	48.44	126.55	117.16	292.15
Mississippi	84.77	0.00	58.58	143.35
North Carolina	133.21	202.48	117.16	452.85
South Carolina	96.88	25.31	117.16	239.35
Tennessee	96.88	253.10	58.58	408.56
Region IV Total	1,017.24	885.85	761.54	2,664.63
Region V				
Illinois	1,332.10	911.16	1,405.92	3,649.18
Indiana	569.17	329.03	527.22	1,425.42
Michigan	1,489.53	2,556.31	1,933.14	5,978.98
Minnesota	217.98	227.79	234.32	680.09
Ohio	1,743.84	1,164.26	1,288.76	4,196.86
Wisconsin	242.20	202.48	351.48	796.16
Region V Total	5,594.82	5,391.03	5,740.84	16,726.69

* Dry Weight = Wet Weight

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-19. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	24.22	50.62	58.58	133.42
Louisiana	12.11	25.31	0.00	37.42
New Mexico	60.55	25.31	0.00	85.86
Oklahoma	84.77	25.31	117.16	227.24
Texas	557.06	354.34	468.64	1,380.04
Region VI Total	738.71	480.89	644.38	1,863.98
Region VII				
Iowa	181.65	75.93	234.32	491.90
Kansas	169.54	0.00	410.06	579.60
Missouri	363.30	151.86	527.22	1,042.38
Nebraska	36.33	50.62	0.00	86.95
Region VII Total	750.82	278.41	1,171.60	2,200.83
Region VIII				
Colorado	169.54	75.93	292.90	538.37
Montana	12.11	0.00	0.00	12.11
North Dakota	0.00	0.00	0.00	0.00
South Dakota	12.11	0.00	0.00	12.11
Utah	72.66	25.31	0.00	97.97
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	266.42	101.24	292.90	660.56
Region IX				
Arizona	133.21	101.24	58.58	293.03
California	968.80	860.54	878.70	2,708.04
Hawaii	12.11	0.00	0.00	12.11
Nevada	48.44	0.00	0.00	48.44
Region IX Total	1,162.56	961.78	937.28	3,061.62
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	36.33	0.00	0.00	36.33
Oregon	121.10	25.31	175.74	322.15
Washington	242.20	101.24	0.00	343.44
Region X Total	399.63	126.55	175.74	701.92
Total U. S.	14,689.43	13,920.48	13,531.98	42,141.89

TABLE E-20. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS DEGREASER SLUDGES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1977

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	114.80	111.29	25.26	251.35
Connecticut	118.90	89.75	46.31	254.96
Rhode Island	0.00	254.89	25.26	280.15
New Hampshire	6.15	0.00	0.00	6.15
Maine	4.10	0.00	4.21	8.31
Vermont	4.10	3.59	0.00	7.69
Region I Total	248.05	459.52	101.04	808.61
Region II				
New Jersey	174.25	75.39	25.26	274.90
New York	200.90	161.55	88.41	450.86
Region II Total	375.15	236.94	113.67	725.76
Region III				
Delaware	2.05	0.00	0.00	2.05
Maryland	22.55	7.18	0.00	29.73
Pennsylvania	141.45	82.57	46.31	270.33
Virginia	0.00	7.18	4.21	11.39
West Virginia	16.40	14.36	8.42	39.18
Region III Total	182.45	111.29	58.94	352.68
Region IV				
Alabama	28.70	21.54	4.21	54.45
Florida	53.30	10.77	4.21	68.28
Georgia	12.30	7.18	12.63	32.11
Kentucky	8.20	17.95	8.42	34.57
Mississippi	14.35	0.00	4.21	18.56
North Carolina	22.55	28.72	8.42	59.69
South Carolina	16.40	3.59	8.42	28.41
Tennessee	16.40	35.90	4.21	56.51
Region IV Total	172.20	125.65	54.73	352.58
Region V				
Illinois	225.50	129.24	101.04	455.78
Indiana	96.35	46.67	37.89	180.91
Michigan	252.15	362.59	138.93	753.67
Minnesota	36.90	32.31	16.84	86.05
Ohio	295.20	165.14	92.62	552.96
Wisconsin	41.00	28.72	25.26	94.98
Region V Total	947.10	764.67	412.58	2,124.35

*Dry Weight = Wet Weight

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-20. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	4.10	7.18	4.21	15.49
Louisiana	2.05	3.59	0.00	5.64
New Mexico	10.25	3.59	0.00	13.84
Oklahoma	14.35	3.59	8.42	26.36
Texas	94.30	50.26	33.68	178.24
Region VI Total	125.05	68.21	46.31	239.57
Region VII				
Iowa	30.75	10.77	16.84	58.36
Kansas	28.70	0.00	29.47	58.17
Missouri	61.50	21.54	37.89	120.93
Nebraska	6.15	7.18	0.00	13.33
Region VII Total	127.10	39.49	84.20	250.79
Region VIII				
Colorado	28.70	10.77	21.05	60.52
Montana	2.05	0.00	0.00	2.05
North Dakota	0.00	0.00	0.00	0.00
South Dakota	2.05	0.00	0.00	2.05
Utah	12.30	3.59	0.00	15.89
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	45.10	14.36	21.05	80.51
Region IX				
Arizona	22.55	14.36	4.21	41.12
California	164.00	122.06	63.15	349.21
Hawaii	2.05	0.00	0.00	2.05
Nevada	8.20	0.00	0.00	8.20
Region IX Total	196.80	136.42	67.36	400.58
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	6.15	0.00	0.00	6.15
Oregon	20.50	3.59	12.63	36.72
Washington	41.00	14.36	0.00	55.36
Region X Total	67.65	17.95	12.63	98.23
Total U. S.	2,486.65	1,974.50	972.51	5,433.66

TABLE E-21. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS ELECTROLESS NICKEL PLATING WASTES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT*; 1977

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	0.00	453.38	87.75	541.13
Connecticut	0.00	365.63	160.88	526.51
Rhode Island	0.00	1,038.38	87.75	1,126.13
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	14.63	14.63
Vermont	0.00	14.63	0.00	14.63
Region I Total	0.00	1,872.02	351.01	2,223.03
Region II				
New Jersey	0.00	307.13	87.75	394.88
New York	0.00	658.13	307.13	965.26
Region II Total	0.00	965.26	394.88	1,360.14
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	29.25	0.00	29.25
Pennsylvania	0.00	336.38	160.88	497.26
Virginia	0.00	29.25	14.63	43.88
West Virginia	0.00	58.50	29.25	87.75
Region III Total	0.00	453.38	204.76	658.14
Region IV				
Alabama	0.00	87.75	14.63	102.38
Florida	0.00	43.88	14.63	58.51
Georgia	0.00	29.25	43.88	73.13
Kentucky	0.00	73.13	29.25	102.38
Mississippi	0.00	0.00	14.63	14.63
North Carolina	0.00	117.00	29.25	146.25
South Carolina	0.00	14.63	29.25	43.88
Tennessee	0.00	146.25	14.63	160.88
Region IV Total	0.00	511.89	190.15	702.04
Region V				
Illinois	0.00	526.50	351.00	877.50
Indiana	0.00	190.13	131.63	321.76
Michigan	0.00	1,477.13	482.63	1,959.76
Minnesota	0.00	131.63	58.50	190.13
Ohio	0.00	672.75	321.75	994.50
Wisconsin	0.00	117.00	87.75	204.75
Region V Total	0.00	3,115.14	1,433.26	4,548.40

* These dry weights can be converted to wet weights by applying a factor of two for a sludge containing 50 percent solids after filtration.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-21. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	29.25	14.63	43.88
Louisiana	0.00	14.63	0.00	14.63
New Mexico	0.00	14.63	0.00	14.63
Oklahoma	0.00	14.63	29.25	43.88
Texas	0.00	204.75	117.00	321.75
Region VI Total	0.00	277.89	160.88	438.77
Region VII				
Iowa	0.00	43.88	58.50	102.38
Kansas	0.00	0.00	102.38	102.38
Missouri	0.00	87.75	131.63	219.38
Nebraska	0.00	29.25	00.00	29.25
Region VII Total	0.00	160.88	292.51	453.39
Region VIII				
Colorado	0.00	43.88	73.13	117.00
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	14.63	0.00	14.63
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	58.51	73.13	131.64
Region IX				
Arizona	0.00	58.50	14.63	73.13
California	0.00	497.25	219.38	716.63
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	555.75	234.01	789.76
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	14.63	43.88	58.51
Washington	0.00	58.50	0.00	58.50
Region X Total	0.00	73.13	43.88	117.01
Total U. S.	0.00	8,043.85	3,378.47	11,422.32

TABLE E-22. TOTAL QUANTITY OF HAZARDOUS METAL HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

EPA Region and State	Total	Iron	Copper	Zinc	Nickel	Aluminum	Chromium	Cadmium	Tin	Lead	Manganese
Region I											
Massachusetts	975.89	135.26	76.01	131.74	162.93	106.65	331.66	18.62	.85	11.83	.34
Connecticut	1,075.70	134.35	96.28	136.25	193.51	113.82	359.30	18.68	1.56	21.68	.27
Rhode Island	1,188.67	189.27	79.00	178.47	172.99	168.99	372.54	13.96	.85	11.83	.77
New Hampshire	17.41	1.49	1.37	2.29	3.27	1.08	7.27	.64	0.00	0.00	0.00
Maine	47.68	5.37	5.64	4.81	9.99	4.48	14.70	.58	.14	1.97	0.00
Vermont	25.28	3.29	1.62	3.76	3.95	2.78	9.26	.61	0.00	0.00	.01
Region I Total	3,330.63	469.03	259.92	457.32	546.64	397.80	1,094.73	53.09	3.40	47.31	1.39
Region II											
New Jersey	997.25	116.72	82.10	131.50	176.76	96.46	357.78	23.02	.85	11.83	.23
New York	1,942.43	243.89	176.06	244.30	350.72	207.10	643.07	32.42	2.98	41.40	.49
Region II Total	2,939.68	360.61	258.16	375.80	527.48	303.56	1,000.85	55.44	3.83	53.23	.72
Region III											
Delaware	5.80	.50	.46	.76	1.09	.36	2.42	.21	0.00	0.00	0.00
Maryland	91.21	10.06	6.44	12.87	15.53	8.08	35.48	2.73	0.00	0.00	.02
Pennsylvania	1,112.14	135.22	99.87	140.17	201.94	113.65	377.13	20.67	1.56	21.68	.25
Virginia	63.44	8.97	6.15	7.75	11.36	7.89	18.68	.51	.14	1.97	.02
West Virginia	173.33	21.91	15.96	21.61	31.44	18.65	56.75	2.75	.28	3.94	.04
Region III Total	1,445.92	176.66	128.88	183.16	261.36	148.63	490.46	26.87	1.98	27.59	.33
Region IV											
Alabama	199.46	25.11	15.39	27.38	33.72	21.17	70.26	4.26	.14	1.97	.06
Florida	228.02	24.19	18.72	29.83	41.46	19.30	86.09	6.29	.14	1.97	.03
Georgia	170.44	20.70	18.35	18.89	33.52	17.58	52.94	2.10	.43	5.91	.02
Kentucky	163.83	22.22	14.85	20.80	28.86	19.28	51.48	2.07	.28	3.94	.05
Mississippi	76.69	7.85	7.92	8.62	15.44	6.28	26.82	1.65	.14	1.97	0.00
North Carolina	245.54	32.59	20.18	32.85	41.82	27.98	81.68	4.13	.28	3.94	.09
South Carolina	132.26	15.02	13.82	14.90	26.11	12.47	43.51	2.20	.28	3.94	.01
Tennessee	219.43	31.31	15.51	31.75	34.29	27.26	73.38	3.71	.14	1.97	.11
Region IV Total	1,435.67	178.99	124.74	185.02	255.22	151.32	486.16	26.41	1.83	25.61	.37
Region V											
Illinois	1,997.03	242.31	189.30	243.17	371.24	204.15	661.98	33.78	3.40	47.31	.39
Indiana	775.41	92.58	73.25	94.46	144.59	77.59	259.97	13.81	1.28	17.74	.14
Michigan	3,287.21	437.39	284.14	427.98	571.17	376.74	1,069.11	49.86	4.68	65.05	1.09
Minnesota	372.00	47.11	33.54	46.98	66.84	40.09	122.77	6.11	.57	7.89	.10
Ohio	2,259.14	273.43	202.48	284.92	410.42	229.47	768.79	42.64	3.12	43.37	.50
Wisconsin	442.04	54.55	43.19	52.83	82.86	46.28	142.91	6.65	.85	11.83	.09
Region V Total	9,132.83	1,147.37	825.90	1,150.34	1,647.12	974.32	3,025.53	152.85	13.90	193.19	2.31

TABLE E-22. (Continued)

Region VI										
Arkansas	75.06	9.96	7.07	9.28	13.54	8.61	23.53	.94	.14	1.97	.02
Louisiana	19.50	2.79	1.17	3.00	2.87	2.42	6.84	.40	0.00	0.00	.01
New Mexico	42.70	4.78	2.99	6.05	7.22	3.86	16.53	1.26	0.00	0.00	.01
Oklahoma	126.45	14.52	13.36	14.14	25.02	12.11	41.09	1.98	.28	3.94	.01
Texas	747.21	90.00	68.78	92.65	137.47	75.53	252.10	13.63	1.13	15.77	.15
Region VI Total	1,010.92	122.05	93.37	125.12	186.12	102.53	340.09	18.21	1.55	21.68	.20
Region VII											
Iowa	272.42	31.84	27.89	31.28	52.91	26.64	89.01	4.36	.57	7.89	.03
Kansas	333.76	37.57	39.48	33.65	69.93	31.39	102.92	4.03	.99	13.80	0.00
Missouri	380.90	68.05	60.51	65.83	113.64	57.04	187.88	8.87	1.28	17.74	.06
Nebraska	44.78	6.08	2.79	6.76	6.82	5.20	16.10	1.01	0.00	0.00	.02
Region VII Total	1,231.86	143.54	130.67	137.52	243.30	120.27	395.91	18.27	2.84	39.43	.11
Region VIII											
Colorado	302.69	35.72	32.16	33.79	59.64	30.04	96.45	4.29	.71	9.86	.03
Montana	5.80	.50	.46	.76	1.09	.36	2.42	.21	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Dakota	5.80	.50	.46	.76	1.09	.36	2.42	.21	0.00	0.00	0.00
Utah	48.50	5.28	3.45	6.81	8.31	4.22	18.95	1.47	0.00	0.00	.01
Wyoming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Region VIII Total	362.79	42.00	36.53	42.12	70.13	34.98	120.24	6.18	.71	9.86	.04
Region IX											
Arizona	154.68	19.03	12.60	20.62	26.90	15.97	54.16	3.25	.14	1.97	.04
California	1,470.91	183.44	131.64	186.29	264.71	155.35	491.76	25.65	2.13	29.57	.37
Hawaii	5.80	.50	.46	.76	1.09	.36	2.42	.21	0.00	0.00	0.00
Nevada	23.21	1.99	1.82	3.05	4.36	1.44	9.69	.86	0.00	0.00	0.00
Region IX Total	1,654.60	204.96	146.52	210.72	297.05	173.12	558.04	29.97	2.27	31.54	.41
Region X											
Alaska	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idaho	17.41	1.49	1.37	2.29	3.27	1.08	7.27	.64	0.00	0.00	0.00
Oregon	179.94	20.39	19.46	19.71	36.10	16.95	58.21	2.77	.43	5.91	.01
Washington	170.83	19.13	11.97	24.21	28.89	15.44	66.11	5.04	0.00	0.00	.04
Region X Total	368.18	41.01	32.80	46.21	68.26	33.47	131.59	8.45	.43	5.91	.05
TOTAL U. S.	22,913.08	2,886.22	2,037.49	2,913.33	4,102.68	2,440.00	7,643.60	395.74	32.74	455.35	5.93

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-23. TOTAL QUANTITY OF CHROMIUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM ELECTROPLATING AND METAL FINISHING INDUSTRY; (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	135.68	136.84	59.14	331.66
Connecticut	140.53	110.35	108.42	359.30
Rhode Island	0.00	313.40	59.14	372.54
New Hampshire	7.27	0.00	0.00	7.27
Maine	4.85	0.00	9.86	14.71
Vermont	4.85	4.41	0.00	9.26
Region I Total	293.18	565.00	236.56	1,094.74
Region II				
New Jersey	205.94	92.70	59.14	357.78
New York	237.44	198.64	206.99	643.07
Region II Total	443.38	291.34	266.13	1,000.85
Region III				
Delaware	2.42	0.00	0.00	2.42
Maryland	26.65	8.83	0.00	35.48
Pennsylvania	167.18	101.52	108.42	377.12
Virginia	0.00	8.83	9.86	18.69
West Virginia	19.38	17.66	19.71	56.75
Region III Total	215.63	136.84	137.99	490.46
Region IV				
Alabama	33.92	26.48	9.86	70.26
Florida	62.99	13.24	9.86	86.09
Georgia	14.54	8.83	29.57	52.94
Kentucky	9.69	22.07	19.71	51.47
Mississippi	16.96	0.00	9.86	26.82
North Carolina	26.65	35.31	19.71	81.67
South Carolina	19.38	4.41	19.71	43.50
Tennessee	19.38	44.14	9.86	73.38
Region IV Total	203.51	154.48	128.14	486.13
Region V				
Illinois	266.51	158.91	236.56	661.98
Indiana	113.87	57.38	88.71	259.96
Michigan	298.01	445.83	325.27	1,069.11
Minnesota	43.61	39.73	39.43	122.77
Ohio	348.89	203.05	216.85	768.79
Wisconsin	48.46	35.31	59.14	142.91
Region V Total	1,119.35	940.21	965.96	3,025.52

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-23. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	4.85	8.83	9.86	23.54
Louisiana	2.42	4.41	0.00	6.83
New Mexico	12.11	4.41	0.00	16.52
Oklahoma	16.96	4.41	19.71	41.08
Texas	111.45	61.80	78.85	252.10
Region VI Total	147.79	83.86	108.42	340.07
Region VII				
Iowa	36.34	13.24	39.43	89.01
Kansas	33.92	0.00	69.00	102.92
Missouri	72.69	26.48	88.71	187.88
Nebraska	7.27	8.83	0.00	16.10
Region VII Total	150.22	48.55	197.14	395.91
Region VIII				
Colorado	33.92	13.24	49.28	96.44
Montana	2.42	0.00	0.00	2.42
North Dakota	0.00	0.00	0.00	0.00
South Dakota	2.42	0.00	0.00	2.42
Utah	14.54	4.41	0.00	18.95
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	53.30	17.65	49.28	120.23
Region IX				
Arizona	26.65	17.66	9.86	54.17
California	193.83	150.08	147.85	491.76
Hawaii	2.42	0.00	0.00	2.42
Nevada	9.69	0.00	0.00	9.69
Region IX Total	232.59	167.74	157.71	558.04
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	7.27	0.00	0.00	7.27
Oregon	24.23	4.41	29.57	58.21
Washington	48.46	17.66	0.00	66.12
Region X Total	79.96	22.07	29.57	131.60
Total U. S.	2,938.93	2,427.74	2,276.90	7,643.55

TABLE E-24. TOTAL QUANTITY OF NICKEL HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	61.00	55.07	46.87	162.94
Connecticut	63.18	44.41	85.93	193.52
Rhode Island	0.00	126.12	46.87	172.99
New Hampshire	3.27	0.00	0.00	3.27
Maine	2.18	0.00	7.81	9.99
Vermont	2.18	1.78	0.00	3.96
Region I Total	131.81	227.38	187.48	546.67
Region II				
New Jersey	92.59	37.30	46.87	176.76
New York	106.75	79.94	164.04	350.73
Region II Total	199.34	117.24	210.91	527.49
Region III				
Delaware	1.09	0.00	0.00	1.09
Maryland	11.98	3.55	0.00	15.53
Pennsylvania	75.16	40.86	85.93	201.95
Virginia	0.00	3.55	7.81	11.36
West Virginia	8.71	7.11	15.62	31.44
Region III Total	96.94	55.07	109.36	261.37
Region IV				
Alabama	15.25	10.66	7.81	33.72
Florida	28.32	5.33	7.81	41.46
Georgia	6.54	3.55	23.43	33.52
Kentucky	4.36	8.88	15.62	28.86
Mississippi	7.62	0.00	7.81	15.43
North Carolina	11.98	14.21	15.62	41.81
South Carolina	8.71	1.78	15.62	26.11
Tennessee	8.71	17.76	7.81	34.28
Region IV Total	91.49	62.17	101.53	255.19
Region V				
Illinois	119.82	63.95	187.48	371.24
Indiana	51.19	23.09	70.30	144.59
Michigan	133.98	179.41	257.78	571.17
Minnesota	19.61	15.99	31.25	66.84
Ohio	156.85	81.71	171.85	410.42
Wisconsin	21.78	14.21	46.87	82.86
Region V Total	503.23	378.36	765.53	1,647.12

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-24. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	2.18	3.55	7.81	13.54
Louisiana	1.09	1.78	0.00	2.87
New Mexico	5.45	1.78	0.00	7.23
Oklahoma	7.62	1.78	15.62	25.02
Texas	50.11	24.87	62.49	137.47
Region VI Total	66.45	33.76	85.92	186.13
Region VII				
Iowa	16.34	5.33	31.25	52.92
Kansas	15.25	0.00	54.68	69.93
Missouri	32.68	10.66	70.30	113.64
Nebraska	3.27	3.55	0.00	6.82
Region VII Total	67.54	19.54	156.23	243.31
Region VIII				
Colorado	15.25	5.33	39.06	59.64
Montana	1.09	0.00	0.00	1.09
North Dakota	0.00	0.00	0.00	0.00
South Dakota	1.09	0.00	0.00	1.09
Utah	6.54	1.78	0.00	8.32
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	23.97	7.11	39.06	70.14
Region IX				
Arizona	11.98	7.11	7.81	26.90
California	87.14	60.40	117.17	264.71
Hawaii	1.09	0.00	0.00	1.09
Nevada	4.36	0.00	0.00	4.36
Region IX Total	104.57	67.51	124.98	297.06
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	3.27	0.00	0.00	3.27
Oregon	10.89	1.78	23.43	36.10
Washington	21.78	7.11	0.00	28.89
Region X Total	35.94	8.89	23.43	68.26
Total U. S.	1,321.28	977.03	1,804.43	4,102.74

TABLE E-25. TOTAL QUANTITY OF ZINC HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	42.73	69.33	19.68	131.74
Connecticut	42.25	55.91	36.09	134.25
Rhode Island	0.00	158.78	19.68	178.46
New Hampshire	2.29	0.00	0.00	2.29
Maine	1.53	0.00	3.28	4.81
Vermont	1.53	2.24	0.00	3.77
Region I Total	90.33	286.26	78.73	455.32
Region II				
New Jersey	64.86	46.96	19.68	131.50
New York	74.77	100.64	68.89	244.30
Region II Total	139.63	147.60	88.57	375.80
Region III				
Delaware	.76	0.00	0.00	.76
Maryland	8.39	4.47	0.00	12.86
Pennsylvania	52.65	51.44	36.09	140.18
Virginia	0.00	4.47	3.28	7.75
West Virginia	6.10	8.95	6.56	21.61
Region III Total	67.90	69.33	45.93	183.16
Region IV				
Alabama	10.68	13.42	3.28	27.38
Florida	19.84	6.71	3.28	29.83
Georgia	4.58	4.47	9.84	18.79
Kentucky	3.05	11.18	6.56	20.79
Mississippi	5.34	0.00	3.28	8.62
North Carolina	8.39	17.89	6.56	32.84
South Carolina	6.10	2.24	6.56	14.90
Tennessee	6.10	22.36	3.28	31.74
Region IV Total	64.08	78.27	42.64	184.99
Region V				
Illinois	83.93	80.51	78.73	243.17
Indiana	35.86	29.07	29.53	94.46
Michigan	93.85	225.87	108.26	427.98
Minnesota	13.73	20.13	13.12	46.98
Ohio	109.87	102.87	72.17	284.91
Wisconsin	15.26	17.89	19.68	52.83
Region V Total	352.50	476.34	321.49	1,150.33

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-25. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	1.53	4.47	3.28	9.28
Louisiana	.76	2.24	0.00	3.00
New Mexico	3.82	2.24	0.00	6.06
Oklahoma	5.34	2.24	6.56	14.14
Texas	35.10	31.31	26.24	92.65
Region VI Total	46.55	42.50	36.08	125.13
Region VII				
Iowa	11.45	6.71	13.12	31.28
Kansas	10.68	0.00	22.96	33.64
Missouri	22.89	13.42	29.53	65.84
Nebraska	2.29	4.47	0.00	6.76
Region VII Total	47.31	24.60	65.61	137.52
Region VIII				
Colorado	10.68	6.71	16.40	33.79
Montana	.76	0.00	0.00	.76
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.76	0.00	0.00	.76
Utah	4.58	2.24	0.00	6.82
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	16.78	8.95	16.40	42.13
Region IX				
Arizona	8.39	8.95	3.28	20.62
California	61.04	76.04	49.21	186.29
Hawaii	.76	0.00	0.00	.76
Nevada	3.05	0.00	0.00	3.05
Region IX Total	73.24	84.99	52.49	210.72
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	2.29	0.00	0.00	2.29
Oregon	7.63	2.24	9.84	19.71
Washington	15.26	8.95	0.00	24.21
Region X Total	25.18	11.19	9.84	46.21
Total U. S.	923.50	1,230.03	757.78	2,911.31

TABLE E-26. TOTAL QUANTITY OF IRON HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS: DRY WEIGHT; 1977

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	27.84	71.18	26.24	125.26
Connecticut	28.83	57.41	48.11	134.35
Rhode Island	0.00	163.03	26.24	189.27
New Hampshire	1.49	0.00	0.00	1.49
Maine	.99	0.00	4.37	5.36
Vermont	.99	2.30	0.00	3.29
Region I Total	60.14	293.92	104.96	459.02
Region II				
New Jersey	42.26	48.22	26.24	116.72
New York	48.72	103.33	91.84	243.89
Region II Total	90.98	151.55	118.08	360.61
Region III				
Delaware	.50	0.00	0.00	.50
Maryland	5.47	4.59	0.00	10.06
Pennsylvania	34.30	52.81	48.11	135.22
Virginia	0.00	4.59	4.37	8.96
West Virginia	3.98	9.18	8.75	21.91
Region III Total	44.25	71.17	61.23	176.65
Region IV				
Alabama	6.96	13.78	4.37	25.11
Florida	12.93	6.89	4.37	24.19
Georgia	2.98	4.59	13.12	20.69
Kentucky	1.99	11.48	8.75	22.22
Mississippi	3.48	0.00	4.37	7.85
North Carolina	5.47	18.37	8.75	32.59
South Carolina	3.98	2.30	8.75	15.03
Tennessee	3.98	22.96	4.37	31.31
Region IV Total	41.77	80.37	56.85	178.99
Region V				
Illinois	54.69	82.66	104.96	242.31
Indiana	23.37	29.85	39.36	92.58
Michigan	61.15	231.92	144.32	437.39
Minnesota	8.95	20.67	17.49	47.11
Ohio	71.59	105.63	96.21	273.43
Wisconsin	9.94	18.37	26.24	54.55
Region V Total	229.69	489.10	428.58	1,147.37

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-26. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	.99	4.59	4.37	9.95
Louisiana	.50	2.30	0.00	2.80
New Mexico	2.49	2.30	0.00	4.79
Oklahoma	3.48	2.30	8.75	14.53
Texas	22.87	32.15	34.99	90.01
Region VI Total	30.33	43.64	48.11	122.08
Region VII				
Iowa	7.46	6.89	17.49	31.84
Kansas	6.96	0.00	30.61	37.57
Missouri	14.91	13.78	39.36	68.05
Nebraska	1.49	4.59	0.00	6.08
Region VII Total	30.82	25.26	87.46	143.54
Region VIII				
Colorado	6.96	6.89	21.87	35.72
Montana	.50	0.00	0.00	.50
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.50	0.00	0.00	.50
Utah	2.98	2.30	0.00	5.28
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	10.94	9.19	21.87	42.00
Region IX				
Arizona	5.47	9.18	4.37	19.02
California	39.77	78.07	65.60	183.44
Hawaii	.50	0.00	0.00	.50
Nevada	1.99	0.00	0.00	1.99
Region IX Total	47.73	87.25	69.97	204.95
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.49	0.00	0.00	1.49
Oregon	4.97	2.30	13.12	20.39
Washington	9.94	9.18	0.00	19.13
Region X Total	16.41	11.48	13.12	41.01
Total U. S.	603.06	1,262.93	1,010.23	2,876.22

TABLE E-27. TOTAL QUANTITY OF ALUMINUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	20.14	63.92	22.59	106.65
Connecticut	20.86	51.55	41.41	113.82
Rhode Island	0.00	146.41	22.59	169.00
New Hampshire	1.08	0.00	0.00	1.08
Maine	.72	0.00	3.76	4.48
Vermont	.72	2.06	0.00	2.78
Region I Total	43.52	263.94	90.35	397.81
Region II				
New Jersey	30.57	43.30	22.59	96.46
New York	35.25	92.79	79.05	207.09
Region II Total	65.82	136.09	101.64	303.55
Region III				
Delaware	.36	0.00	0.00	.36
Maryland	3.96	4.12	0.00	8.08
Pennsylvania	24.82	47.43	41.41	113.66
Virginia	0.00	4.12	3.76	7,89
West Virginia	2.88	8.25	7.53	18.65
Region III Total	32.02	63.92	52.70	148.64
Region IV				
Alabama	5.04	12.37	3.76	21.17
Florida	9.35	6.19	3.76	19.30
Georgia	2.16	4.12	11.29	17.57
Kentucky	1.44	10.31	7.53	19.28
Mississippi	2.52	0.00	3.76	6.28
North Carolina	3.96	16.50	7.53	27.99
South Carolina	2.88	2.06	7.53	12.47
Tennessee	2.88	20.62	3.76	27.26
Region IV Total	30.23	72.17	48.92	151.32
Region V				
Illinois	39.56	74.23	90.35	204.14
Indiana	16.90	26.81	33.88	77.59
Michigan	44.24	208.27	124.23	376.74
Minnesota	6.47	18.56	15.06	40.09
Ohio	51.79	94.86	82.82	229.47
Wisconsin	7.19	16.50	22.59	46.28
Region V Total	166.15	439.23	368.93	974.31

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-27. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.71	4.12	3.76	8.59
Louisiana	.36	2.06	0.00	2.42
New Mexico	1.80	2.06	0.00	3.86
Oklahoma	2.52	2.06	7.53	12.11
Texas	16.54	28.87	30.12	75.53
Region VI Total	21.93	39.17	41.41	102.51
Region VII				
Iowa	5.40	6.19	15.06	26.65
Kansas	5.04	0.00	26.35	31.39
Missouri	10.79	12.37	33.88	57.04
Nebraska	1.08	4.12	0.00	5.20
Region VII Total	22.31	22.68	75.29	120.28
Region VIII				
Colorado	5.04	6.19	18.82	30.05
Montana	.36	0.00	0.00	.36
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.36	0.00	0.00	.36
Utah	2.16	2.06	0.00	4.22
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	7.92	8.25	18.82	34.99
Region IX				
Arizona	3.96	8.25	3.76	15.97
California	28.77	70.11	56.47	155.35
Hawaii	.36	0.00	0.00	.36
Nevada	1.44	0.00	0.00	1.44
Region IX Total	34.53	78.36	60.23	173.12
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.08	0.00	0.00	1.08
Oregon	3.60	2.06	11.29	16.95
Washington	7.19	8.25	0.00	15.44
Region X Total	11.87	10.31	11.29	33.47
Total U. S.	436.30	1,134.12	869.58	2,440.00

TABLE E-28. TOTAL QUANTITY OF COPPER HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	25.53	22.11	28.37	76.01
Connecticut	26.44	17.83	52.01	96.28
Rhode Island	0.00	50.63	28.37	79.00
New Hampshire	1.37	0.00	0.00	1.37
Maine	.91	0.00	4.73	5.64
Vermont	.91	.71	0.00	1.62
Region I Total	55.16	91.28	113.48	259.92
Region II				
New Jersey	38.75	14.98	28.37	82.10
New York	44.68	32.09	99.29	176.06
Region II Total	83.43	47.07	127.66	258.16
Region III				
Delaware	.46	0.00	0.00	.46
Maryland	5.01	1.43	0.00	6.44
Pennsylvania	31.46	16.40	52.01	99.87
Virginia	0.00	1.43	4.73	6.16
West Virginia	3.65	2.85	9.46	15.96
Region III Total	40.58	22.11	66.20	128.89
Region IV				
Alabama	6.38	4.28	4.73	15.39
Florida	11.85	2.14	4.73	18.72
Georgia	2.74	1.43	14.18	18.35
Kentucky	1.82	3.57	9.46	14.85
Mississippi	3.19	0.00	4.73	7.92
North Carolina	5.01	5.71	9.46	20.18
South Carolina	3.65	.71	9.46	13.82
Tennessee	3.65	7.13	4.73	15.51
Region IV Total	38.29	24.97	61.48	124.74
Region V				
Illinois	50.15	25.67	113.48	189.30
Indiana	21.43	9.27	42.55	73.25
Michigan	56.08	72.03	156.03	284.14
Minnesota	8.21	6.42	18.91	33.54
Ohio	65.65	32.80	104.02	202.47
Wisconsin	9.12	5.71	28.37	43.20
Region V Total	210.64	151.90	463.36	825.90

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-28. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	.91	1.43	4.73	7.07
Louisiana	.46	.71	0.00	1.17
New Mexico	2.28	.71	0.00	2.99
Oklahoma	3.19	.71	9.46	13.36
Texas	20.97	9.98	37.83	68.78
Region VI Total	27.81	13.54	52.02	93.37
Region VII				
Iowa	6.84	2.14	18.91	27.89
Kansas	6.38	0.00	33.10	39.48
Missouri	13.68	4.28	42.55	60.51
Nebraska	1.37	1.43	0.00	2.80
Region VII Total	28.27	7.85	94.56	130.68
Region VIII				
Colorado	6.38	2.14	23.64	32.16
Montana	.46	0.00	0.00	.46
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.46	0.00	0.00	.46
Utah	2.74	.71	0.00	3.45
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	10.04	2.85	23.64	36.53
Region IX				
Arizona	5.01	2.85	4.73	12.59
California	36.47	24.25	70.92	131.64
Hawaii	.46	0.00	0.00	.46
Nevada	1.82	0.00	0.00	1.82
Region IX Total	43.76	27.10	75.65	146.51
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.37	0.00	0.00	1.37
Oregon	4.56	.71	14.18	19.45
Washington	9.12	2.85	0.00	11.97
Region X Total	15.05	3.56	14.18	32.79
Total U. S.	553.03	392.23	1,092.23	2,037.49

TABLE E-29. TOTAL QUANTITY OF LEAD HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	0.00	11.83	11.83
Connecticut	0.00	0.00	21.68	21.68
Rhode Island	0.00	0.00	11.83	11.83
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	1.97	1.97
Vermont	0.00	0.00	0.00	0.00
Region I Total	0.00	0.00	47.31	47.31
Region II				
New Jersey	0.00	0.00	11.83	11.83
New York	0.00	0.00	41.40	41.40
Region II Total	0.00	0.00	53.23	53.23
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	0.00	0.00
Pennsylvania	0.00	0.00	21.68	21.68
Virginia	0.00	0.00	1.97	1.97
West Virginia	0.00	0.00	3.94	3.94
Region III Total	0.00	0.00	27.59	27.59
Region IV				
Alabama	0.00	0.00	1.97	1.97
Florida	0.00	0.00	1.97	1.97
Georgia	0.00	0.00	5.91	5.91
Kentucky	0.00	0.00	3.94	3.94
Mississippi	0.00	0.00	1.97	1.97
North Carolina	0.00	0.00	3.94	3.94
South Carolina	0.00	0.00	3.94	3.94
Tennessee	0.00	0.00	1.97	1.97
Region IV Total	0.00	0.00	25.61	25.61
Region V				
Illinois	0.00	0.00	47.31	47.31
Indiana	0.00	0.00	17.74	17.74
Michigan	0.00	0.00	65.05	65.05
Minnesota	0.00	0.00	7.89	7.89
Ohio	0.00	0.00	43.37	43.37
Wisconsin	0.00	0.00	11.83	11.83
Region V Total	0.00	0.00	193.19	193.19

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-29. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	0.00	1.97	1.97
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	3.94	3.94
Texas	0.00	0.00	15.77	15.77
Region VI Total	0.00	0.00	21.68	21.68
Region VII				
Iowa	0.00	0.00	7.89	7.89
Kansas	0.00	0.00	13.80	13.80
Missouri	0.00	0.00	17.74	17.74
Nebraska	0.00	0.00	0.00	0.00
Region VII Total	0.00	0.00	39.43	39.43
Region VIII				
Colorado	0.00	0.00	9.86	9.86
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	0.00	9.86	9.86
Region IX				
Arizona	0.00	0.00	1.97	1.97
California	0.00	0.00	29.57	29.57
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	0.00	31.54	31.54
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	5.91	5.91
Washington	0.00	0.00	0.00	0.00
Region X Total	0.00	0.00	5.91	5.91
Total U. S.	0.00	0.00	455.35	455.35

TABLE E-30. TOTAL QUANTITY OF CADMIUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	12.04	5.71	.88	18.63
Connecticut	12.47	4.61	1.60	18.68
Rhode Island	0.00	13.08	.88	13.96
New Hampshire	.64	0.00	0.00	.64
Maine	.43	0.00	.15	.58
Vermont	.43	.18	0.00	.61
Region I Total	26.01	23.58	3.51	53.10
Region II				
New Jersey	18.27	3.87	.88	23.02
New York	21.07	8.29	3.06	32.42
Region II Total	39.34	12.16	3.94	55.44
Region III				
Delaware	.21	0.00	0.00	.21
Maryland	2.36	.37	0.00	2.73
Pennsylvania	14.83	4.24	1.60	20.67
Virginia	0.00	.37	.15	.52
West Virginia	1.72	.74	.29	2.75
Region III Total	19.12	5.72	2.04	26.88
Region IV				
Alabama	3.01	1.11	.15	4.27
Florida	5.59	.55	.15	6.29
Georgia	1.29	.37	.44	2.10
Kentucky	.86	.92	.29	2.07
Mississippi	1.50	0.00	.15	1.65
North Carolina	2.36	1.47	.29	4.12
South Carolina	1.72	.18	.29	2.19
Tennessee	1.72	1.84	.15	3.71
Region IV Total	18.05	6.44	1.91	26.40
Region V				
Illinois	23.64	6.63	3.50	33.77
Indiana	10.10	2.40	1.31	13.81
Michigan	26.44	18.61	4.81	49.86
Minnesota	3.87	1.66	.58	6.11
Ohio	30.95	8.48	3.21	42.64
Wisconsin	4.30	1.47	.88	6.65
Region V Total	99.30	39.25	14.29	152.84

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-30. (Continued)

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region VI				
Arkansas	.43	.37	.15	.95
Louisiana	.21	.18	0.00	.39
New Mexico	1.07	.18	0.00	1.25
Oklahoma	1.50	.18	.29	1.97
Texas	9.89	2.58	1.17	13.64
Region VI Total	13.10	3.49	1.61	18.20
Region VII				
Iowa	3.22	.55	.58	4.35
Kansas	3.01	0.00	1.02	4.03
Missouri	6.45	1.11	1.31	8.87
Nebraska	.64	.37	0.00	1.01
Region VII Total	13.32	2.03	2.91	18.26
Region VIII				
Colorado	3.01	.55	.73	4.29
Montana	.21	0.00	0.00	.21
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.21	0.00	0.00	.21
Utah	1.29	.18	0.00	1.47
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	4.72	.73	.73	6.18
Region IX				
Arizona	2.36	.74	.15	3.25
California	17.20	6.26	2.19	25.65
Hawaii	.21	0.00	0.00	.21
Nevada	.86	0.00	0.00	.86
Region IX Total	20.63	7.00	2.34	29.97
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.64	0.00	0.00	.64
Oregon	2.15	.18	.44	2.77
Washington	4.30	.74	0.00	5.04
Region X Total	7.09	.92	.44	8.45
Total U. S.	260.68	101.32	33.72	395.72

TABLE E-31. TOTAL QUANTITY OF TIN HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	0.00	.85	.85
Connecticut	0.00	0.00	1.56	1.56
Rhode Island	0.00	0.00	.85	.85
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	.14	.14
Vermont	0.00	0.00	0.00	0.00
Region I Total	0.00	0.00	3.40	3.40
Region II				
New Jersey	0.00	0.00	.85	.85
New York	0.00	0.00	2.98	2.98
Region II Total	0.00	0.00	3.83	3.83
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	0.00	0.00
Pennsylvania	0.00	0.00	1.56	1.56
Virginia	0.00	0.00	.14	.14
West Virginia	0.00	0.00	.28	.28
Region III Total	0.00	0.00	1.98	1.98
Region IV				
Alabama	0.00	0.00	.14	.14
Florida	0.00	0.00	.14	.14
Georgia	0.00	0.00	.43	.43
Kentucky	0.00	0.00	.28	.28
Mississippi	0.00	0.00	.14	.14
North Carolina	0.00	0.00	.28	.28
South Carolina	0.00	0.00	.28	.28
Tennessee	0.00	0.00	.14	.14
Region IV Total	0.00	0.00	1.83	1.83
Region V				
Illinois	0.00	0.00	3.40	3.40
Indiana	0.00	0.00	1.28	1.28
Michigan	0.00	0.00	4.68	4.68
Minnesota	0.00	0.00	.57	.57
Ohio	0.00	0.00	3.12	3.12
Wisconsin	0.00	0.00	.85	.85
Region V Total	0.00	0.00	13.90	13.90

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-31. (Continued)

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region VI				
Arkansas	0.00	0.00	.14	.14
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	.28	.28
Texas	0.00	0.00	1.13	1.13
Region VI Total	0.00	0.00	1.55	1.55
Region VII				
Iowa	0.00	0.00	.57	.57
Kansas	0.00	0.00	.99	.99
Missouri	0.00	0.00	1.28	1.28
Nebraska	0.00	0.00	0.00	0.00
Region VII Total	0.00	0.00	2.84	2.84
Region VIII				
Colorado	0.00	0.00	.71	.71
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	0.00	.71	.71
Region IX				
Arizona	0.00	0.00	.14	.14
California	0.00	0.00	2.13	2.13
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	0.00	2.27	2.27
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	.43	.43
Washington	0.00	0.00	0.00	0.00
Region X Total	0.00	0.00	.43	.43
Total U. S.	0.00	0.00	32.74	32.74

TABLE E-32. TOTAL QUANTITY OF MANGANESE HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1977

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	.34	0.00	.34
Connecticut	0.00	.27	0.00	.27
Rhode Island	0.00	.77	0.00	.77
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	0.00	0.00
Vermont	0.00	.01	0.00	.01
Region I Total	0.00	1.39	0.00	1.39
Region II				
New Jersey	0.00	.23	0.00	.23
New York	0.00	.49	0.00	.49
Region II Total	0.00	.72	0.00	.72
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	.02	0.00	.02
Pennsylvania	0.00	.25	0.00	.25
Virginia	0.00	.02	0.00	.02
West Virginia	0.00	.04	0.00	.04
Region III Total	0.00	.33	0.00	.33
Region IV				
Alabama	0.00	.06	0.00	.06
Florida	0.00	.03	0.00	.03
Georgia	0.00	.02	0.00	.02
Kentucky	0.00	.05	0.00	.05
Mississippi	0.00	0.00	0.00	0.00
North Carolina	0.00	.09	0.00	.09
South Carolina	0.00	.01	0.00	.01
Tennessee	0.00	.11	0.00	.11
Region IV Total	0.00	.37	0.00	.37
Region V				
Illinois	0.00	.39	0.00	.39
Indiana	0.00	.14	0.00	.14
Michigan	0.00	1.09	0.00	1.09
Minnesota	0.00	.10	0.00	.10
Ohio	0.00	.50	0.00	.50
Wisconsin	0.00	.09	0.00	.09
Region V Total	0.00	2.31	0.00	2.31

Note: Total Industry Wastes = Potentially Hazardous Wastes

TABLE E-32. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	0.00	.02	0.00	.02
Louisiana	0.00	.01	0.00	.01
New Mexico	0.00	.01	0.00	.01
Oklahoma	0.00	.01	0.00	.01
Texas	0.00	.15	0.00	.15
Region VI Total	0.00	.20	0.00	.20
Region VII				
Iowa	0.00	.03	0.00	.03
Kansas	0.00	0.00	0.00	0.00
Missouri	0.00	.06	0.00	.06
Nebraska	0.00	.02	0.00	.02
Region VII Total	0.00	.11	0.00	.11
Region VIII				
Colorado	0.00	.03	0.00	.03
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	.01	0.00	.01
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	.04	0.00	.04
Region IX				
Arizona	0.00	.04	0.00	.04
California	0.00	.37	0.00	.37
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	.41	0.00	.41
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	.01	0.00	.01
Washington	0.00	.04	0.00	.04
Region X Total	0.00	.05	0.00	.05
Total U. S.	0.00	5.93	0.00	5.93

TABLE E-33. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WASTES DESTINED FOR LAND DISPOSAL FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	2,153.85	3,188.90	1,235.14	6,577.89
Connecticut	2,230.77	2,571.69	2,282.76	7,085.22
Rhode Island	0.00	7,303.61	1,245.14	8,548.75
New Hampshire	115.38	0.00	0.00	115.38
Maine	76.92	0.00	207.52	284.44
Vermont	76.92	102.87	0.00	179.79
Region I Total	4,653.84	13,167.07	4,970.56	22,791.47
Region II				
New Jersey	3,269.24	2,160.22	1,245.14	6,674.60
New York	3,769.24	4,629.05	4,358.00	12,756.29
Region II Total	7,038.48	6,789.27	5,603.14	19,430.89
Region III				
Delaware	38.46	0.00	0.00	38.46
Maryland	423.08	205.74	0.00	628.82
Pennsylvania	2,653.85	2,365.96	2,282.76	7,302.57
Virginia	0.00	205.74	207.52	413.26
West Virginia	307.69	411.47	415.05	1,134.21
Region III Total	3,423.08	3,188.91	2,905.33	9.517.32
Region IV				
Alabama	538.46	617.21	207.52	1,363.19
Florida	1,000.00	308.60	207.52	1,516.12
Georgia	230.77	205.74	622.57	1,059.08
Kentucky	153.85	514.34	415.05	1,083.24
Mississippi	269.23	0.00	207.52	476.75
North Carolina	423.08	822.94	415.05	1,661.07
South Carolina	307.69	102.87	415.05	825.61
Tennessee	307.69	1,028.68	207.52	1,543.89
Region IV Total	3,230.77	3,600.38	2,697.80	9,528.95
Region V				
Illinois	4,230.78	3,703.24	4,980.57	12,914.59
Indiana	1,807.70	1,337.28	1,867.71	5,012.69
Michigan	4,730.78	10,389.64	6,848.28	21,968.70
Minnesota	692.31	925.81	830.09	2,448.21
Ohio	5,538.47	4,731.92	4,565.52	14,835.91
Wisconsin	769.23	822.94	1,245.14	2,837.31
Region V Total	17,769.27	21,910.83	20,337.31	60,017.41

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-33. (Continued)

EPA Region and State	Plant Size (Employees) 16	 38	 87	Total
Region VI				
Arkansas	76.92	205.74	207.52	490.18
Louisiana	38.46	102.87	0.00	141.33
New Mexico	192.31	102.87	0.00	295.18
Oklahoma	269.23	102.87	415.05	787.15
Texas	1,769.23	1,440.15	1,660.19	4,869.57
Region VI Total	2,346.15	1,954.50	2,282.76	6,583.41
Region VII				
Iowa	576.92	308.60	830.09	1,715.61
Kansas	538.46	0.00	1,452.67	1,991.13
Missouri	1,153.85	617.21	1,867.71	3,638.77
Nebraska	115.38	205.74	0.00	321.12
Region VII Total	2,384.61	1,131.55	4,150.47	7,666.63
Region VIII				
Colorado	538.46	308.60	1,037.62	1,884.68
Montana	38.46	0.00	0.00	38.46
North Dakota	0.00	0.00	0.00	0.00
South Dakota	38.46	0.00	0.00	38.46
Utah	230.77	102.87	0.00	333.64
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	846.15	411.47	1,037.62	2,295.24
Region IX				
Arizona	423.08	411.47	207.52	1,042.07
California	3,076.93	3,497.50	3,112.85	9,687.28
Hawaii	38.46	0.00	0.00	38.46
Nevada	153.85	0.00	0.00	153.85
Region IX Total	3,692.32	3,908.97	3,320.37	10,921.66
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	115.38	0.00	0.00	115.38
Oregon	384.62	102.87	622.57	1,110.06
Washington	769.23	411.47	0.00	1,180.70
Region X Total	1,269.23	514.34	622.57	2,406.14
Total U. S.	46,653.90	56,577.29	47,927.93	151,159.12

TABLE E-34. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS WATER POLLUTION CONTROL SLUDGES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	1,115.07	1,421.35	636.66	3,173.08
Connecticut	1,154.90	1,146.25	1,167.21	3,468.36
Rhode Island	0.00	3,255.35	636.66	3,892.01
New Hampshire	59.74	0.00	0.00	59.74
Maine	39.82	0.00	106.11	145.93
Vermont	39.82	45.85	0.00	85.67
Region I Total	2,409.35	5,868.80	2,546.64	10,824.79
Region II				
New Jersey	1,692.52	636.66	636.66	2,965.84
New York	1,951.38	2,063.25	2,228.31	6,242.94
Region II Total	3,643.90	2,699.91	2,864.97	9,208.78
Region III				
Delaware	19.91	0.00	0.00	19.91
Maryland	219.03	91.70	0.00	310.73
Pennsylvania	1,373.93	1,054.55	1,167.21	3,595.69
Virginia	0.00	91.70	106.11	197.81
West Virginia	159.30	183.40	212.22	554.92
Region III Total	1,772.17	1,421.35	1,485.54	4,679.06
Region IV				
Alabama	278.77	275.10	106.11	659.98
Florida	517.71	137.55	106.11	761.37
Georgia	119.47	91.70	318.33	529.50
Kentucky	79.65	229.25	212.22	521.12
Mississippi	139.38	0.00	106.11	245.49
North Carolina	219.29	366.80	212.22	798.31
South Carolina	159.30	45.85	212.22	417.37
Tennessee	159.30	458.50	212.22	830.02
Region IV Total	1,672.87	1,604.75	1,485.54	4,763.16
Region V				
Illinois	2,190.32	1,650.60	2,546.64	6,387.56
Indiana	935.86	596.05	954.99	2,486.90
Michigan	2,449.18	4,630.85	3,501.63	10,581.66
Minnesota	358.42	412.65	424.44	1,195.51
Ohio	2,867.33	2,109.10	2,334.42	7,310.85
Wisconsin	398.24	366.80	636.66	1,401.70
Region V Total	9,199.35	9,766.05	10,398.78	29,364.18

* These dry weights can be converted to wet weights by applying a factor of five for a sludge containing 20 percent solids.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-34. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	39.82	91.70	106.11	237.63
Louisiana	19.91	45.85	0.00	65.76
New Mexico	99.56	45.85	0.00	145.41
Oklahoma	139.38	45.85	212.22	397.45
Texas	915.95	641.90	848.88	2,406.73
Region VI Total	1,214.62	871.15	1,167.21	3,252.98
Region VII				
Iowa	298.68	137.55	424.44	860.67
Kansas	278.77	0.00	742.77	1,021.54
Missouri	597.36	275.10	954.99	1,827.45
Nebraska	59.74	91.70	0.00	151.44
Region VII Total	1,234.55	504.35	2,122.20	3,861.10
Region VIII				
Colorado	278.77	137.55	530.55	946.87
Montana	19.91	0.00	0.00	19.91
North Dakota	0.00	0.00	0.00	0.00
South Dakota	19.91	0.00	0.00	19.91
Utah	119.47	45.85	0.00	165.32
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	438.06	183.40	530.55	1,152.01
Region IX				
Arizona	219.03	183.40	106.11	508.54
California	1,592.96	1,558.90	1,591.65	4,743.51
Hawaii	19.91	0.00	0.00	19.91
Nevada	79.65	0.00	0.00	79.65
Region IX Total	1,911.55	1,742.30	1,697.76	5,351.61
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	59.74	0.00	0.00	59.74
Oregon	199.12	45.85	318.33	563.30
Washington	398.24	183.40	0.00	581.64
Region X Total	657.10	229.25	318.33	1,204.68
Total U. S.	24,153.52	24,891.31	24,617.52	73,662.35

TABLE E-35. QUANTITY OF TOTAL AND POTENTIALLY HAZARDOUS PROCESS WASTES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	888.39	1,027.84	460.44	2,376.67
Connecticut	920.12	828.90	844.14	2,593.16
Rhode Island	0.00	2,354.08	460.44	2,814.52
New Hampshire	47.59	0.00	0.00	47.59
Maine	31.73	0.00	76.74	108.47
Vermont	31.73	33.16	0.00	64.89
Region I Total	1,919.56	4,243.98	1,841.76	8,005.30
Region II				
New Jersey	1,348.45	696.28	460.44	2,505.17
New York	1,554.68	1,492.02	1,611.54	4,658.24
Region II Total	2,903.13	2,188.30	2,071.98	7,163.41
Region III				
Delaware	15.86	0.00	0.00	15.86
Maryland	174.51	66.31	0.00	240.82
Pennsylvania	1,094.62	762.59	844.14	2,701.35
Virginia	0.00	66.31	76.74	143.05
West Virginia	126.91	132.62	153.48	413.01
Region III Total	1,411.90	1,027.83	1,074.36	3.514.09
Region IV				
Alabama	222.10	198.94	76.74	497.78
Florida	412.47	99.47	76.74	588.68
Georgia	95.18	66.31	230.22	391.71
Kentucky	63.46	165.78	153.48	382.72
Mississippi	111.05	0.00	76.74	187.79
North Carolina	174.51	265.25	153.48	593.24
South Carolina	126.91	33.16	153.48	313.55
Tennessee	126.91	331.56	76.74	535.21
Region IV Total	1,332.59	1,160.47	997.62	3,490.68
Region V				
Illinois	1,745.05	1,193.62	1,841.76	4,780.43
Indiana	745.61	431.03	690.66	1,867.30
Michigan	1,951.28	3,348.77	2,532.41	7,832.46
Minnesota	285.55	298.40	306.96	890.91
Ohio	2,284.43	1,525.18	1,688.28	5,497.89
Wisconsin	317.28	265.25	460.44	1,042.97
Region V Total	7,329.20	7,062.25	7,520.51	21,911.96

* Dry Weight = Wet Weight.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-35. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	31.73	66.31	76.74	174.78
Louisiana	15.86	33.16	0.00	49.02
New Mexico	79.32	33.16	0.00	112.48
Oklahoma	111.05	33.16	153.48	297.69
Texas	729.75	464.19	613.92	1,807.86
Region VI Total	967.71	629.98	844.14	2,441.83
Region VII				
Iowa	237.96	99.47	306.96	644.39
Kansas	222.10	0.00	537.18	759.28
Missouri	475.92	198.94	690.66	1,365.52
Nebraska	47.59	66.31	0.00	113.90
Region VII Total	983.57	364.72	1,534.80	2,883.09
Region VIII				
Colorado	222.10	99.47	383.70	705.27
Montana	15.86	0.00	0.00	15.86
North Dakota	0.00	0.00	0.00	0.00
South Dakota	15.86	0.00	0.00	15.86
Utah	95.18	33.16	0.00	128.34
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	349.00	132.63	383.70	865.33
Region IX				
Arizona	174.51	132.62	76.74	383.87
California	1,269.13	1,127.31	1,151.10	3,547.54
Hawaii	15.86	0.00	0.00	15.86
Nevada	63.46	0.00	0.00	63.46
Region IX Total	1,522.96	1,259.93	1,227.84	4,010.73
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	47.59	0.00	0.00	47.59
Oregon	158.64	33.16	230.22	422.02
Washington	317.28	132.62	0.00	449.90
Region X Total	523.51	165.78	230.22	919.51
Total U. S.	19,243.13	18,235.87	17,726.93	55,205.93

TABLE E-36. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS DEGREASER SLUDGES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	150.39	145.79	33.09	329.27
Connecticut	155.76	117.57	60.67	334.00
Rhode Island	0.00	333.91	33.09	367.00
New Hampshire	8.06	0.00	0.00	8.06
Maine	5.37	0.00	5.52	10.89
Vermont	5.37	4.70	0.00	10.07
Region I Total	324.95	601.97	132.37	1,059.29
Region II				
New Jersey	228.27	98.76	33.09	360.12
New York	263.18	211.63	115.82	590.63
Region II Total	491.45	310.39	148.91	950.75
Region III				
Delaware	2.69	0.00	0.00	2.69
Maryland	29.54	9.41	0.00	38.95
Pennsylvania	185.30	108.17	60.67	354.14
Virginia	0.00	9.41	5.52	14.93
West Virginia	21.48	18.81	11.03	51.32
Region III Total	239.01	145.80	77.22	462.03
Region IV				
Alabama	37.60	28.22	5.52	71.34
Florida	69.82	14.11	5.52	89.45
Georgia	16.11	9.41	16.55	42.07
Kentucky	10.74	23.51	11.03	45.28
Mississippi	18.80	0.00	5.52	24.32
North Carolina	29.54	37.62	11.03	78.19
South Carolina	21.48	4.70	11.03	37.21
Tennessee	21.48	47.03	5.52	74.03
Region IV Total	225.57	164.60	71.72	461.89
Region V				
Illinois	295.41	169.30	132.36	597.07
Indiana	126.22	61.14	49.64	236.99
Michigan	330.32	474.99	182.00	987.31
Minnesota	48.34	42.33	22.06	112.73
Ohio	386.71	216.33	121.33	724.38
Wisconsin	53.71	37.62	33.09	124.42
Region V Total	1,240.71	1,001.71	540.48	2,782.90

* Dry Weight = Wet Weight.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-36. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	5.37	9.41	5.52	20.30
Louisiana	2.69	4.70	0.00	7.39
New Mexico	13.43	4.70	0.00	18.13
Oklahoma	18.80	4.70	11.03	34.53
Texas	123.53	65.84	44.12	233.49
Region VI Total	163.82	89.35	60.67	313.84
Region VII				
Iowa	40.28	14.11	22.06	76.45
Kansas	37.60	0.00	38.61	76.21
Missouri	80.57	28.22	49.64	158.43
Nebraska	8.06	9.41	0.00	17.47
Region VII Total	166.51	51.74	110.31	328.56
Region VIII				
Colorado	37.60	14.11	27.58	79.28
Montana	2.69	0.00	0.00	2.69
North Dakota	0.00	0.00	0.00	0.00
South Dakota	2.69	0.00	0.00	2.69
Utah	16.11	4.70	0.00	20.82
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	59.09	18.81	27.58	105.48
Region IX				
Arizona	29.54	18.81	5.52	53.87
California	214.84	159.90	82.73	457.47
Hawaii	2.69	0.00	0.00	2.69
Nevada	10.74	0.00	0.00	10.74
Region IX Total	257.81	178.71	88.25	524.77
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	8.06	0.00	0.00	8.06
Oregon	26.86	4.70	16.55	48.11
Washington	53.71	18.81	00.00	72.52
Region X Total	88.63	23.51	16.55	128.69
Total U. S.	3,257.55	2,586.59	1,274.06	7,118.20

TABLE E-37. QUANTITY OF TOTAL INDUSTRY AND POTENTIALLY HAZARDOUS ELECTROLESS NICKEL PLATING WASTES GENERATED FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS) METRIC TONS; DRY WEIGHT*; 1983

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	593.92	114.95	708.87
Connecticut	0.00	478.97	210.75	689.72
Rhode Island	0.00	1,360.27	114.95	1,475.22
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	19.16	19.16
Vermont	0.00	19.16	0.00	19.16
Region I Total	0.00	2,452.32	459.81	2,912.13
Region II				
New Jersey	0.00	402.33	114.95	517.28
New York	0.00	862.14	802.33	1,664.47
Region II Total	0.00	1,264.47	917.28	2,181.75
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	38.32	0.00	38.32
Pennsylvania	0.00	440.65	210.75	651.40
Virginia	0.00	38.32	19.16	57.48
West Virginia	0.00	76.64	38.32	114.96
Region III Total	0.00	593.93	268.23	862.16
Region IV				
Alabama	0.00	114.95	19.16	134.11
Florida	0.00	57.48	19.16	76.64
Georgia	0.00	38.32	57.48	95.80
Kentucky	0.00	95.79	38.32	134.11
Mississippi	0.00	0.00	19.16	19.16
North Carolina	0.00	153.27	38.32	191.59
South Carolina	0.00	19.16	38.32	57.48
Tennessee	0.00	191.59	19.16	210.75
Region IV Total	0.00	670.56	249.08	919.64
Region V				
Illinois	0.00	689.72	459.81	1,149.53
Indiana	0.00	249.06	172.43	421.49
Michigan	0.00	1,935.03	632.24	2,567.27
Minnesota	0.00	172.43	76.64	249.06
Ohio	0.00	881.30	421.49	1,302.80
Wisconsin	0.00	153.27	114.95	268.22
Region V Total	0.00	4,080.81	1,877.56	5,958.37

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* These dry weights can be converted to wet weights by applying a factor of two for a sludge containing 50 percent solids after filtration.

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-37. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	38.32	19.16	57.48
Louisiana	0.00	19.16	0.00	19.16
New Mexico	0.00	19.16	0.00	19.16
Oklahoma	0.00	19.16	38.32	57.48
Texas	0.00	268.22	153.27	421.49
Region VI Total	0.00	364.02	210.75	574.77
Region VII				
Iowa	0.00	57.48	76.64	134.12
Kansas	0.00	0.00	134.11	134.11
Missouri	0.00	114.95	172.43	287.38
Netraska	0.00	38.32	0.00	38.32
Region VII Total	0.00	210.75	383.18	593.93
Region VIII				
Colorado	0.00	57.48	95.79	153.27
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	19.16	0.00	19.16
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	76.64	95.79	172.43
Region IX				
Arizona	0.00	76.64	19.16	95.80
California	0.00	651.40	287.38	938.78
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	728.04	306.54	1,034.58
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	19.16	57.48	76.64
Washington	0.00	76.64	00.00	76.64
Region X Total	0.00	95.80	57.48	153.28
Total U. S.	0.00	10,537.34	4,825.70	15,363.04

TABLE E-38. TOTAL QUANTITY OF HAZARDOUS METAL HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Total	Iron	Copper	Zinc	Nickel	Aluminum	Chromium	Cadmium	Tin	Lead	Manganese
Region I											
Massachusetts	1,265.32	164.10	99.57	172.58	213.44	139.72	434.47	24.40	1.11	15.49	.44
Connecticut	1,409.19	176.00	126.13	178.49	253.50	149.11	470.69	24.47	2.04	28.41	.35
Rhode Island	1,557.15	247.95	103.49	233.79	226.62	221.38	488.03	18.28	1.11	15.49	1.01
New Hampshire	22.79	1.95	1.79	3.00	4.28	1.41	9.52	.84	0.00	0.00	0.00
Maine	62.46	7.03	7.39	6.30	13.09	5.87	19.26	.75	.19	2.58	0.00
Vermont	33.13	4.31	2.13	4.93	5.18	3.64	12.13	.80	0.00	0.00	.01
Region I Total	4,350.04	601.34	340.50	599.09	716.11	521.13	1,434.10	69.54	4.45	61.97	1.81
Region II											
New Jersey	1,306.38	152.90	107.55	172.2[illegible]	231.55	126.37	468.69	30.15	1.11	15.49	.30
New York	2,544.58	319.50	230.64	320.04	459.45	271.29	842.42	42.47	3.90	54.23	.64
Region II Total	3,850.96	472.40	338.19	492.31	691.00	397.66	1,311.11	72.62	5.01	69.72	.94
Region III											
Delaware	7.60	.65	.60	1.00	1.43	.47	3.17	.28	0.00	0.00	0.00
Maryland	119.50	13.18	8.44	16.85	20.35	10.59	46.48	3.58	0.00	0.00	.03
Pennsylvania	1,456.91	177.14	130.83	183.62	264.54	148.89	494.03	27.08	2.04	28.41	.33
Virginia	83.14	11.75	8.06	10.16	14.89	10.33	24.48	.67	.19	2.58	.03
West Virginia	227.08	28.70	20.90	28.31	41.19	24.44	74.35	3.60	.37	5.16	.06
Region III Total	1,894.23	231.42	168.83	239.94	342.40	194.72	642.51	35.21	2.60	36.15	.45
Region IV											
Alabama	261.31	32.90	20.16	35.87	44.17	27.74	92.04	5.58	.19	2.58	.08
Florida	298.71	31.69	24.52	39.07	54.31	25.29	112.78	8.24	.19	2.58	.04
Georgia	223.26	27.11	24.03	24.75	43.91	23.02	69.35	2.75	.56	7.75	.03
Kentucky	214.60	29.10	19.45	27.24	37.81	25.25	67.43	2.72	.37	5.16	.07
Mississippi	100.56	10.29	10.37	11.29	20.22	8.23	35.13	2.16	.19	2.68	0.00
North Carolina	321.64	42.69	26.43	43.03	54.78	36.66	107.00	5.41	.37	5.16	.11
South Carolina	173.26	19.68	18.10	19.52	34.21	16.33	57.00	2.88	.37	5.16	.01
Tennessee	287.45	41.02	20.31	41.59	44.92	35.71	96.13	4.86	.19	2.58	.14
Region IV Total	1,880.79	234.48	163.37	242.36	334.33	198.23	636.86	34.60	2.43	33.65	.48
Region V											
Illinois	2,616.13	317.43	247.98	318.56	486.33	267.43	867.20	44.25	4.46	61.98	.51
Indiana	1,015.78	121.28	95.96	123.74	189.41	101.65	340.56	18.09	1.67	23.24	.18
Michigan	4,306.24	572.98	372.22	560.66	748.23	493.52	1,400.53	65.32	6.13	85.22	1.43
Minnesota	487.30	61.71	43.93	61.55	87.56	52.52	160.82	8.01	.74	10.33	.13
Ohio	3,959.43	358.19	265.24	373.24	537.65	300.60	1,007.11	55.85	4.09	56.81	.65
Wisconsin	579.05	71.46	56.58	69.21	108.55	60.62	187.21	8.71	1.11	15.49	.11
Region V Total	11,963.93	1,503.05	1,081.91	1,506.96	2,157.73	1,276.34	3,963.43	200.23	18.20	253.07	3.01

TABLE E-38. (Continued)

Region VI										
Arkansas	98.36	13.05	9.26	12.16	17.74	11.28	30.83	1.24	.19	2.58	.03
Louisiana	25.53	3.66	1.53	3.93	3.75	3.17	8.96	.52	0.00	0.00	.01
New Mexico	55.94	6.26	3.92	7.93	9.46	5.06	21.65	1.65	0.00	0.00	.01
Oklahoma	151.64	19.03	17.50	18.52	32.78	15.86	53.82	2.59	.37	5.16	.01
Texas	960.85	117.90	90.10	121.37	180.08	98.94	330.25	17.86	1.49	20.65	.20
Region VI Total	1,324.32	159.90	122.31	163.91	243.81	134.32	445.51	23.86	2.05	28.40	.26
Region VII											
Iowa	356.87	41.71	36.54	40.97	69.32	34.90	116.61	5.71	.74	10.33	.04
Kansas	437.23	49.22	51.72	44.08	91.61	41.12	134.82	5.28	1.30	18.08	0.00
Missouri	760.99	89.15	79.27	86.24	148.87	74.73	246.12	11.62	1.67	23.24	.08
Nebraska	58.69	7.97	3.66	8.86	8.93	6.82	21.09	1.33	0.00	0.00	.03
Region VII Total	1,613.78	188.05	171.19	180.15	318.73	157.57	518.64	23.94	3.71	51.65	.15
Region VIII											
Colorado	396.51	46.79	42.13	44.27	78.12	39.36	126.34	5.62	.93	12.91	.04
Montana	7.60	.65	.60	1.00	1.43	.47	3.17	.28	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Dakota	7.60	.65	.60	1.00	1.43	.47	3.17	.28	0.00	0.00	0.00
Utah	63.56	6.92	4.52	8.93	10.89	5.53	24.83	1.93	0.00	0.00	.01
Wyoming	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Region VIII Total	475.27	55.01	47.85	55.20	91.87	45.83	157.51	8.11	.93	12.91	.05
Region IX											
Arizona	202.64	24.93	16.50	27.01	35.24	20.92	70.96	4.25	.19	2.58	.06
California	1,826.88	240.31	172.45	244.03	346.77	203.51	644.20	33.60	2.79	38.74	.48
Hawaii	7.60	.65	.60	1.00	1.43	.47	3.17	.28	0.00	0.00	0.00
Nevada	30.42	2.61	2.39	4.00	5.71	1.88	12.70	1.13	0.00	0.00	0.00
Region IX Total	2,067.54	268.50	191.94	276.04	389.15	226.78	731.03	39.26	2.98	41.32	.54
Region X											
Alaska	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Idaho	22.79	1.95	1.79	3.00	4.28	1.41	9.52	.84	0.00	0.00	0.00
Oregon	235.74	26.71	25.49	25.82	47.30	22.21	76.26	3.63	.56	7.75	.01
Washington	223.80	25.06	15.68	31.71	37.85	20.23	86.61	6.60	0.00	0.00	.06
Region X Total	482.33	53.72	42.96	60.53	89.43	43.85	172.39	11.07	.56	7.75	.07
TOTAL U. S.	29,903.19	3,767.87	2,669.05	3,816.49	5,374.56	3,196.42	10,013.09	518.44	42.92	596.59	7.76

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-39. TOTAL QUANTITY OF CHROMIUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT: 1983

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	177.74	179.26	77.47	434.47
Connecticut	184.09	144.56	142.04	470.69
Rhode Island	0.00	410.56	77.47	488.03
New Hampshire	9.52	0.00	0.00	9.52
Maine	6.35	0.00	12.91	19.26
Vermont	6.35	5.78	0.00	12.13
Region I Total	384.05	740.16	309.89	1,434.10
Region II				
New Jersey	269.78	121.43	77.47	468.68
New York	311.05	260.21	271.16	842.42
Region II Total	580.83	381.64	348.63	1,311.10
Region III				
Delaware	3.17	0.00	0.00	3.17
Maryland	34.91	11.57	0.00	46.48
Pennsylvania	219.00	133.00	142.04	494.04
Virginia	0.00	11.57	12.91	24.48
West Virginia	25.39	23.13	25.82	74.34
Region III Total	282.47	179.27	180.77	642.51
Region IV				
Alabama	44.44	34.70	12.91	92.05
Florida	82.52	17.35	12.91	112.78
Georgia	19.04	11.57	38.74	69.35
Kentucky	12.70	28.91	25.82	67.43
Mississippi	22.22	0.00	12.91	35.13
North Carolina	34.91	46.26	25.82	106.99
South Carolina	25.39	5.78	25.82	56.99
Tennessee	25.39	57.83	12.91	96.13
Region IV Total	266.61	202.40	167.84	636.85
Region V				
Illinois	349.13	208.17	309.89	867.19
Indiana	149.17	75.17	116.21	340.55
Michigan	390.39	584.03	426.11	1,400.53
Minnesota	57.13	52.04	51.65	160.82
Ohio	457.05	266.00	284.07	1,007.12
Wisconsin	63.48	46.26	77.47	187.21
Region V Total	1,466.35	1,231.67	1,265.40	3,963.42

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-39. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	6.35	11.57	12.91	30.83
Louisiana	3.17	5.78	0.00	8.96
New Mexico	15.87	5.78	0.00	21.65
Oklahoma	22.22	5.78	25.82	53.82
Texas	146.00	80.96	103.30	330.25
Region VI Total	193.61	109.87	142.03	445.51
Region VII				
Iowa	47.61	17.35	51.65	116.61
Kansas	44.44	0.00	90.39	134.83
Missouri	95.22	34.70	116.21	246.13
Nebraska	9.52	11.57	0.00	21.09
Region VII Total	196.79	63.62	258.25	518.66
Region VIII				
Colorado	44.44	17.35	64.56	126.35
Montana	3.17	0.00	0.00	3.17
North Dakota	0.00	0.00	0.00	0.00
South Dakota	3.17	0.00	0.00	3.17
Utah	19.04	5.78	0.00	24.82
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	69.82	23.13	64.56	157.51
Region IX				
Arizona	34.91	23.13	12.91	70.95
California	253.91	196.61	193.68	644.20
Hawaii	3.17	0.00	0.00	3.17
Nevada	12.70	0.00	0.00	12.70
Region IX Total	304.69	219.74	206.59	731.02
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	9.52	0.00	0.00	9.52
Oregon	31.74	5.78	38.74	76.26
Washington	63.48	23.13	0.00	86.61
Region X Total	104.74	28.91	38.74	172.39
Total U. S.	3,849.96	3,180.41	2,982.70	10,013.07

TABLE E-40. TOTAL QUANTITY OF NICKEL HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	79.91	72.14	61.40	213.44
Connecticut	82.76	58.18	112.56	253.50
Rhode Island	0.00	165.22	61.40	226.62
New Hampshire	4.28	0.00	0.00	4.28
Maine	2.85	0.00	10.23	13.09
Vermont	2.85	2.33	0.00	5.18
Region I Total	172.65	297.87	245.59	716.11
Region II				
New Jersey	121.29	48.87	61.40	231.56
New York	139.84	104.72	214.89	459.45
Region II Total	261.13	153.59	276.29	691.01
Region III				
Delaware	1.43	0.00	0.00	1.43
Maryland	15.70	4.65	0.00	20.35
Pennsylvania	98.46	53.52	112.56	264.54
Virginia	0.00	4.65	10.23	14.88
West Virginia	11.42	9.31	20.47	41.20
Region III Total	127.01	72.13	143.26	342.40
Region IV				
Alabama	19.98	13.96	10.23	44.17
Florida	37.10	6.98	10.23	54.31
Georgia	8.56	4.65	30.70	43.91
Kentucky	5.71	11.64	20.47	37.82
Mississippi	9.99	0.00	10.23	20.22
North Carolina	15.70	18.62	20.47	54.79
South Carolina	11.42	2.33	20.47	34.22
Tennessee	11.42	23.27	10.23	44.92
Region IV Total	119.88	81.45	133.03	334.36
Region V				
Illinois	156.96	83.77	245.59	486.32
Indiana	67.06	30.25	92.10	189.41
Michigan	175.51	235.03	337.69	748.23
Minnesota	25.68	20.94	40.93	87.55
Ohio	205.47	107.04	225.13	537.64
Wisconsin	28.54	18.62	61.40	108.56
Region V Total	659.22	495.65	1,002.84	2,157.71

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-40. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	2.85	4.65	10.23	17.73
Louisiana	1.43	2.33	0.00	3.76
New Mexico	7.13	2.33	0.00	9.46
Oklahoma	9.99	2.33	20.47	32.79
Texas	65.64	32.58	81.86	180.08
Region VI Total	87.04	44.22	112.56	243.82
Region VII				
Iowa	21.40	6.98	40.93	69.31
Kansas	19.98	0.00	71.63	91.61
Missouri	42.81	13.96	92.10	148.87
Nebraska	4.28	4.65	0.00	8.93
Region VII Total	88.47	25.59	204.66	318.72
Region VIII				
Colorado	19.98	6.98	51.17	78.13
Montana	1.43	0.00	0.00	1.43
North Dakota	0.00	0.00	0.00	0.00
South Dakota	1.43	0.00	0.00	1.43
Utah	8.56	2.33	0.00	10.89
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	31.40	9.31	51.17	91.88
Region IX				
Arizona	15.70	9.31	10.23	35.24
California	114.15	79.12	153.50	346.77
Hawaii	1.43	0.00	0.00	1.43
Nevada	5.71	0.00	0.00	5.71
Region IX Total	136.99	88.43	163.73	389.15
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	4.28	0.00	0.00	4.28
Oregon	14.27	2.33	30.70	47.30
Washington	28.54	9.31	0.00	37.85
Region X Total	47.09	11.64	30.70	89.43
Total U. S.	1,730.88	1,279.88	2,363.83	5,374.59

TABLE E-41. TOTAL QUANTITY OF ZINC HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	55.97	90.82	25.79	172.58
Connecticut	57.97	73.24	47.27	178.48
Rhode Island	0.00	208.01	25.79	233.80
New Hampshire	3.00	0.00	0.00	3.00
Maine	2.00	0.00	4.30	6.30
Vermont	2.00	2.93	0.00	4.93
Region I Total	120.94	375.00	103.15	599.09
Region II				
New Jersey	84.96	61.52	25.79	172.27
New York	97.95	131.83	90.25	320.03
Region II Total	182.91	193.35	116.04	492.30
Region III				
Delaware	1.00	0.00	0.00	1.00
Maryland	10.99	5.86	0.00	16.85
Pennsylvania	68.97	67.38	47.27	183.62
Virginia	0.00	5.86	4.30	10.16
West Virginia	8.00	11.72	8.60	28.32
Region III Total	88.96	90.82	60.17	239.95
Region IV				
Alabama	13.99	17.58	4.30	35.87
Florida	25.99	8.79	4.30	39.08
Georgia	6.00	5.86	12.89	24.75
Kentucky	4.00	14.65	8.60	27.25
Mississippi	7.00	0.00	4.30	11.30
North Carolina	10.99	23.44	8.60	43.03
South Carolina	8.00	2.93	8.60	19.53
Tennessee	8.00	29.30	4.30	41.60
Region IV Total	83.97	102.55	55.89	242.41
Region V				
Illinois	109.95	105.47	103.14	318.56
Indiana	46.98	38.09	38.68	123.75
Michigan	122.94	295.90	141.82	560.66
Minnesota	17.99	26.37	17.19	61.55
Ohio	143.93	134.76	94.55	373.24
Wisconsin	19.99	23.44	25.79	69.22
Region V Total	461.78	624.03	421.17	1,506.98

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-41. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	2.00	5.86	4.30	12.16
Louisiana	1.00	2.93	0.00	3.93
New Mexico	5.00	2.93	0.00	7.93
Oklahoma	7.00	2.93	8.60	18.53
Texas	45.98	41.02	34.38	121.38
Region VI Total	60.98	55.67	47.28	163.93
Region VII				
Iowa	14.99	8.79	17.19	40.97
Kansas	13.99	0.00	30.08	44.08
Missouri	29.99	17.58	38.68	86.24
Nebraska	3.00	5.86	0.00	8.86
Region VII Total	61.97	32.23	85.95	180.15
Region VIII				
Colorado	13.99	8.79	21.49	44.27
Montana	1.00	0.00	0.00	1.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	1.00	0.00	0.00	1.00
Utah	6.00	2.93	0.00	8,93
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	21.99	11.72	21.49	55.20
Region IX				
Arizona	10.99	11.72	4.30	27.01
California	79.96	99.61	64.46	244.03
Hawaii	1.00	0.00	0.00	1.00
Nevada	4.00	0.00	0.00	4.00
Region IX Total	95.95	111.33	68.76	276.04
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	3.00	0.00	0.00	3.00
Oregon	10.00	2.93	12.89	25.82
Washington	19.99	11.72	0.00	31.71
Region X Total	32.99	14.65	12.89	60.53
Total U. S.	1,212.44	1,611.35	992.79	3,816.58

TABLE E-42. TOTAL QUANTITY OF IRON HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

	Plant Size (Employees)			
EPA Region and State	16	38	87	Total
Region I				
Massachusetts	36.47	93.25	34.37	164.09
Connecticut	37.77	75.20	63.02	175.99
Rhode Island	0.00	213.57	34.37	247.94
New Hampshire	1.95	0.00	0.00	1.95
Maine	1.30	0.00	5.73	7.03
Vermont	1.30	3.01	0.00	4.31
Region I Total	78.79	385.03	137.49	601.31
Region II				
New Jersey	55.36	63.17	34.37	152.90
New York	63.82	135.36	120.31	319.49
Region II Total	119.18	198.53	154.68	472.39
Region III				
Delaware	.65	0.00	0.00	.65
Maryland	7.16	6.02	0.00	13.18
Pennsylvania	44.94	69.19	63.02	177.15
Virginia	0.00	6.02	5.73	11.75
West Virginia	5.21	12.03	11.46	28.70
Region III Total	57.96	93.26	80.21	231.43
Region IV				
Alabama	9.12	18.05	5.73	32.90
Florida	16.93	9.02	5.73	31.68
Georgia	3.91	6.02	17.19	27.12
Kentucky	2.61	15.04	11.46	29.11
Mississippi	4.56	0.00	5.73	10.29
North Carolina	7.16	24.06	11.46	42.68
South Carolina	5.21	3.01	11.46	19.68
Tennessee	5.21	30.08	5.73	41.02
Region IV Total	54.71	105.28	74.49	234.48
Region V				
Illinois	71.64	108.29	137.50	317.43
Indiana	30.61	39.10	51.56	121.27
Michigan	80.11	303.81	189.06	572.98
Minnesota	11.72	27.07	22.92	61.71
Ohio	93.78	138.37	126.04	358.19
Wisconsin	13.03	24.06	34.37	71.46
Region V Total	300.89	640.70	561.45	1,503.04

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-42. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	1.30	6.02	5.73	13.05
Louisiana	.65	3.01	0.00	3.66
New Mexico	3.26	3.01	0.00	6.27
Oklahoma	4.56	3.01	11.46	19.03
Texas	29.96	42.11	45.83	117.90
Region VI Total	39.73	57.16	63.02	159.91
Region VII				
Iowa	9.77	9.02	22.92	41.71
Kansas	9.12	0.00	40.10	49.22
Missouri	19.54	18.05	51.56	89.15
Nebraska	1.95	6.02	0.00	7.97
Region VII Total	40.38	33.09	114.58	188.05
Region VIII				
Colorado	9.12	9.02	28.65	46.79
Montana	.65	0.00	0.00	.65
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.65	0.00	0.00	.65
Utah	3.91	3.01	0.00	6.92
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	14.33	12.03	28.65	55.01
Region IX				
Arizona	7.16	12.03	5.73	24.92
California	52.10	102.27	85.94	240.31
Hawaii	.65	0.00	0.00	.65
Nevada	2.61	0.00	0.00	2.61
Region IX Total	62.52	114.30	91.67	268.49
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.95	0.00	0.00	1.95
Oregon	6.51	3.01	17.19	26.71
Washington	13.03	12.03	0.00	25.06
Region X Total	21.49	15.04	17.19	53.72
Total U. S.	789.98	1,654.42	1,323.43	3,767.83

TABLE E-43. TOTAL QUANTITY OF ALUMINUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	26.39	83.74	29.59	139.72
Connecticut	27.33	67.53	53.25	148.11
Rhode Island	0.00	191.79	39.59	231.38
New Hampshire	1.41	0.00	0.00	1.41
Maine	.94	0.00	4.93	5.87
Vermont	.94	2.70	0.00	3.64
Region I Total	57.01	345.76	127.36	530.13
Region II				
New Jersey	40.05	56.73	29.59	126.37
New York	46.17	121.56	103.56	271.29
Region II Total	86.22	178.29	133.15	397.66
Region III				
Delaware	.47	0.00	0.00	.47
Maryland	5.18	5.40	0.00	10.58
Pennsylvania	32.51	62.13	54.25	148.89
Virginia	0.00	5.40	4.93	10.33
West Virginia	3.77	10.81	9.86	24.44
Region III Total	41.93	83.74	69.04	194.71
Region IV				
Alabama	6.60	16.21	4.93	27.74
Florida	12.25	8.10	4.93	25.28
Georgia	2.83	5.40	14.79	23.02
Kentucky	1.88	13.51	9.86	25.25
Mississippi	3.30	0.00	4.93	8.23
North Carolina	5.18	21.61	9.86	36.65
South Carolina	3.77	2.70	9.86	16.33
Tennessee	3.77	27.01	4.93	35.71
Region IV Total	39.58	94.54	64.09	198.21
Region V				
Illinois	51.83	97.25	118.35	267.43
Indiana	22.15	35.12	44.38	101.65
Michigan	57.95	272.83	162.74	493.52
Minnesota	8.48	24.31	19.73	52.52
Ohio	67.85	124.26	108.49	300.60
Wisconsin	9.42	21.61	29.59	60.62
Region V Total	217.68	575.38	483.28	1,276.34

Note: Total Industry Wastes = Potentially Hazardous Wastes,

TABLE E-43. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	.94	5.40	4.93	11.27
Louisiana	.47	2.70	0.00	3.17
New Mexico	2.36	2.70	0.00	5.06
Oklahoma	3.30	2.70	9.86	15.86
Texas	21.67	37.82	39.45	98.94
Region VI Total	28.74	51.32	54.24	134.30
Region VII				
Iowa	7.07	8.10	19.73	34.90
Kansas	6.60	0.00	34.52	41.12
Missouri	14.14	16.21	44.38	74.73
Nebraska	1.41	5.40	0.00	6.81
Region VII Total	29.22	29.71	98.63	157.56
Region VIII				
Colorado	6.60	8.10	24.66	39.36
Montana	.47	0.00	0.00	.47
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.47	0.00	0.00	.47
Utah	2.83	2.70	0.00	5.53
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	10.37	10.80	24.66	45.83
Region IX				
Arizona	5.18	10.81	4.93	20.92
California	37.69	91.84	73.97	203.50
Hawaii	.47	0.00	0.00	.47
Nevada	1.88	0.00	0.00	1.88
Region IX Total	45.22	102.65	78.90	226.77
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.41	0.00	0.00	1.41
Oregon	4.71	2.70	14.79	22.20
Washington	9.42	10.81	0.00	20.23
Region X Total	15.54	13.51	14.79	43.84
Total U. S.	571.51	1,485.70	1,148.14	3,205.35

TABLE E-44. TOTAL QUANTITY OF COPPER HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	33.44	28.96	37.16	99.56
Connecticut	34.64	23.36	68.13	126.13
Rhode Island	0.00	66.33	37.16	103.49
New Hampshire	1.79	0.00	0.00	1.79
Maine	1.19	0.00	6.19	7.38
Vermont	1.19	.93	0.00	2.12
Region I Total	72.25	119.58	148.64	340.47
Region II				
New Jersey	50.76	19.62	37.16	107.54
New York	58.53	42.04	130.08	230.65
Region II Total	109.29	61.66	167.24	338.19
Region III				
Delaware	.60	0.00	0.00	.60
Maryland	6.57	1.87	0.00	8.44
Pennsylvania	41.21	21.49	68.13	130.83
Virginia	0.00	1.87	6.19	8.06
West Virginia	4.78	3.74	12.39	20.91
Region III Total	53.16	28.97	86.71	168.84
Region IV				
Alabama	8.36	5.61	6.19	20.16
Florida	15.53	2.80	6.19	24.52
Georgia	3.58	1.87	18.58	24.03
Kentucky	2.39	4.67	12.39	19.45
Mississippi	4.18	0.00	6.19	10.37
North Carolina	6.57	7.47	12.39	26.43
South Carolina	4.78	.93	12.39	18.10
Tennessee	4.78	9.34	6.19	20.31
Region IV Total	50.17	32.69	80.51	163.37
Region V				
Illinois	65.69	33.63	148.66	247.98
Indiana	28.07	12.14	55.75	95.96
Michigan	73.46	94.36	204.40	372.22
Minnesota	10.75	8.41	24.78	43.93
Ohio	86.00	42.97	136.27	265.24
Wisconsin	11.94	7.47	37.16	56.58
Region V Total	275.91	198.98	607.02	1,081.91

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-44. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	1.19	1.87	6.19	9.25
Louisiana	.60	.93	0.00	1.53
New Mexico	2.99	.93	0.00	3.92
Oklahoma	4.18	.93	12.39	17.50
Texas	27.47	13.08	49.55	90.10
Region VI Total	36.43	17.74	68.13	122.30
Region VII				
Iowa	8.96	2.80	24.78	36.54
Kansas	8.36	0.00	43.36	51.72
Missouri	17.92	5.61	55.75	79.28
Nebraska	1.79	1.87	0.00	3.66
Region VII Total	37.03	10.28	123.89	171.20
Region VIII				
Colorado	8.36	2.80	30.97	42.13
Montana	.60	0.00	0.00	.60
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.60	0.00	0.00	.60
Utah	3.58	.93	0.00	4.51
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	13.14	3.73	30.97	47.84
Region IX				
Arizona	6.57	3.74	6.19	16.50
California	47.78	31.76	92.91	172.45
Hawaii	.60	0.00	0.00	.60
Nevada	2.39	0.00	0.00	2.39
Region IX Total	57.34	35.50	99.10	191.94
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	1.79	0.00	0.00	1.79
Oregon	5.97	.93	18.58	25.48
Washington	11.94	3.74	0.00	15.68
Region X Total	19.70	4.67	18.58	42.95
Total U. S.	724.42	513.80	1,430.79	2,669.01

TABLE E-45. TOTAL QUANTITY OF LEAD HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			
	16	38	87	Total
Region I				
Massachusetts	0.00	0.00	15.49	15.49
Connecticut	0.00	0.00	28.41	28.41
Rhode Island	0.00	0.00	15.49	15.49
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	2.58	2.58
Vermont	0.00	0.00	0.00	0.00
Region I Total	0.00	0.00	61.97	61.97
Region II				
New Jersey	0.00	0.00	15.49	15.49
New York	0.00	0.00	54.23	54.23
Region II Total	0.00	0.00	69.72	69.72
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	0.00	0.00
Pennsylvania	0.00	0.00	28.41	28.41
Virginia	0.00	0.00	2.58	2.58
West Virginia	0.00	0.00	5.16	5.16
Region III Total	0.00	0.00	36.15	36.15
Region IV				
Alabama	0.00	0.00	2.58	2.58
Florida	0.00	0.00	2.58	2.58
Georgia	0.00	0.00	7.75	7.75
Kentucky	0.00	0.00	5.16	5.16
Mississippi	0.00	0.00	2.58	2.58
North Carolina	0.00	0.00	5.16	5.16
South Carolina	0.00	0.00	5.16	5.16
Tennessee	0.00	0.00	2.58	2.58
Region IV Total	0.00	0.00	33.55	33.55
Region V				
Illinois	0.00	0.00	61.98	61.98
Indiana	0.00	0.00	23.24	23.24
Michigan	0.00	0.00	85.22	85.22
Minnesota	0.00	0.00	10.33	10.33
Ohio	0.00	0.00	56.81	56.81
Wisconsin	0.00	0.00	15.49	15.49
Region V Total	0.00	0.00	253.07	253.07

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-45. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	0.00	2.58	2.58
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	5.16	5.16
Texas	0.00	0.00	20.66	20.66
Region VI Total	0.00	0.00	28.40	28.40
Region VII				
Iowa	0.00	0.00	10.33	10.33
Kansas	0.00	0.00	18.08	18.08
Missouri	0.00	0.00	23.24	23.24
Nebraska	0.00	0.00	0.00	0.00
Region VII Total	0.00	0.00	51.65	51.65
Region VIII				
Colorado	0.00	0.00	12.91	12.91
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	0.00	12.91	12.91
Region IX				
Arizona	0.00	0.00	2.58	2.58
California	0.00	0.00	38.74	38.74
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	0.00	41.32	41.32
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	7.75	7.75
Washington	0.00	0.00	0.00	0.00
Region X Total	0.00	0.00	7.75	7.75
Total U. S.	0.00	0.00	596.49	596.49

TABLE E-46. TOTAL QUANTITY OF CADMIUM HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	15.77	7.48	1.15	24.40
Connecticut	16.33	6.03	2.10	24.46
Rhode Island	0.00	17.14	1.15	18.29
New Hampshire	.84	0.00	0.00	.84
Maine	.56	0.00	.19	.75
Vermont	.56	.24	0.00	.80
Region I Total	34.06	30.89	4.59	69.54
Region II				
New Jersey	23.93	5.07	1.15	30.15
New York	27.60	10.86	4.01	42.47
Region II Total	51.53	15.93	5.16	72.62
Region III				
Delaware	.28	0.00	0.00	.28
Maryland	3.10	.48	0.00	3.58
Pennsylvania	19.43	5.55	2.10	27.08
Virginia	0.00	.48	.19	.67
West Virginia	2.25	.97	.38	3.60
Region III Total	25.06	7.48	2.67	35.21
Region IV				
Alabama	3.94	1.45	.19	5.58
Florida	7.32	.72	.19	8.23
Georgia	1.69	.48	.57	2.74
Kentucky	1.13	1.21	.38	2.72
Mississippi	1.97	0.00	.19	2.16
North Carolina	3.10	1.93	.38	5.41
South Carolina	2.25	.24	.38	2.87
Tennessee	2.25	2.41	.19	4.85
Region IV Total	23.65	8.44	2.47	34.56
Region V				
Illinois	30.97	8.69	4.59	44.25
Indiana	13.23	3.14	1.72	18.09
Michigan	34.63	24.38	6.31	65.32
Minnesota	5.07	2.17	.76	8.00
Ohio	40.55	11.10	4.20	55.85
Wisconsin	5.63	1.93	1.15	8.71
Region V Total	130.08	51.41	18.73	200.22

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-46. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	.56	.48	.19	1.23
Louisiana	.28	.24	0.00	.52
New Mexico	1.41	.24	0.00	1.65
Oklahoma	1.97	.24	.38	2.59
Texas	12.95	3.38	1.53	17.86
Region VI Total	17.17	4.58	2.10	23.85
Region VII				
Iowa	4.22	.72	.76	5.70
Kansas	3.94	0.00	1.34	5.28
Missouri	8.45	1.45	1.72	11.62
Nebraska	.84	.48	0.00	1.32
Region VII Total	17.45	2.65	3.82	23.92
Region VIII				
Colorado	3.94	.72	.96	5.62
Montana	.28	0.00	0.00	.28
North Dakota	0.00	0.00	0.00	0.00
South Dakota	.28	0.00	0.00	.28
Utah	1.69	.24	0.00	1.93
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	6.19	.96	.96	8.11
Region IX				
Arizona	3.10	.97	.19	4.25
California	22.53	8.21	2.87	33.61
Hawaii	.28	0.00	0.00	.28
Nevada	1.13	0.00	0.00	1.13
Region IX Total	27.04	9.18	3.06	39.28
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	.84	0.00	0.00	.84
Oregon	2.82	.24	.57	3.63
Washington	5.63	.97	0.00	6.60
Region X Total	9.29	1.21	.57	11.07
Total U. S.	341.52	132.73	44.13	518.38

TABLE E-47. TOTAL QUANTITY OF TIN HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region I				
Massachusetts	0.00	0.00	1.11	1.11
Connecticut	0.00	0.00	2.04	2.04
Rhode Island	0.00	0.00	1.11	1.11
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	.19	.19
Vermont	0.00	0.00	0.00	0.00
Region I Total	0.00	0.00	4.45	4.45
Region II				
New Jersey	0.00	0.00	1.11	1.11
New York	0.00	0.00	3.90	3.90
Region II Total	0.00	0.00	5.01	5.01
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	0.00	0.00	0.00
Pennsylvania	0.00	0.00	2.04	2.04
Virginia	0.00	0.00	.19	.19
West Virginia	0.00	0.00	.37	.37
Region III Total	0.00	0.00	2.60	2.60
Region IV				
Alabama	0.00	0.00	.19	.19
Florida	0.00	0.00	.19	.19
Georgia	0.00	0.00	.56	.56
Kentucky	0.00	0.00	.37	.37
Mississippi	0.00	0.00	.19	.19
North Carolina	0.00	0.00	.37	.37
South Carolina	0.00	0.00	.37	.37
Tennessee	0.00	0.00	.19	.19
Region IV Total	0.00	0.00	2.43	2.43
Region V				
Illinois	0.00	0.00	4.46	4.46
Indiana	0.00	0.00	1.67	1.67
Michigan	0.00	0.00	6.13	6.13
Minnesota	0.00	0.00	.74	.74
Ohio	0.00	0.00	4.09	4.09
Wisconsin	0.00	0.00	1.11	1.11
Region V Total	0.00	0.00	18.20	18.20

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-47. (Continued)

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region VI				
Arkansas	0.00	0.00	.19	.19
Louisiana	0.00	0.00	0.00	0.00
New Mexico	0.00	0.00	0.00	0.00
Oklahoma	0.00	0.00	.37	.37
Texas	0.00	0.00	1.49	1.49
Region VI Total	0.00	0.00	2.05	2.05
Region VII				
Iowa	0.00	0.00	.74	.74
Kansas	0.00	0.00	1.30	1.30
Missouri	0.00	0.00	1.67	1.67
Nebraska	0.00	0.00	0.00	0.00
Region VII Total	0.00	0.00	3.71	3.71
Region VIII				
Colorado	0.00	0.00	.93	.93
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	0.00	0.00	0.00
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	0.00	.93	.93
Region IX				
Arizona	0.00	0.00	.19	.19
California	0.00	0.00	2.79	2.79
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	0.00	2.98	2.98
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	0.00	.56	.56
Washington	0.00	0.00	0.00	0.00
Region X Total	0.00	0.00	.56	.56
Total U. S.	0.00	0.00	41.92	41.92

TABLE E-48. TOTAL QUANTITY OF MANGANESE HYDROXIDE WASTES GENERATED IN THE WATER POLLUTION CONTROL SLUDGES FROM THE ELECTROPLATING AND METAL FINISHING INDUSTRY (JOB SHOPS); METRIC TONS; DRY WEIGHT; 1983

EPA Region and State	Plant Size (Employees)			Total
	16	38	87	
Region I				
Massachusetts	0.00	.44	0.00	.44
Connecticut	0.00	.35	0.00	.35
Rhode Island	0.00	1.01	0.00	1.01
New Hampshire	0.00	0.00	0.00	0.00
Maine	0.00	0.00	0.00	0.00
Vermont	0.00	.01	0.00	.01
Region I Total	0.00	1.81	0.00	1.81
Region II				
New Jersey	0.00	.30	0.00	.30
New York	0.00	.64	0.00	.64
Region II Total	0.00	.94	0.00	.94
Region III				
Delaware	0.00	0.00	0.00	0.00
Maryland	0.00	.03	0.00	.03
Pennsylvania	0.00	.33	0.00	.33
Virginia	0.00	.03	0.00	.03
West Virginia	0.00	.06	0.00	.06
Region III Total	0.00	.45	0.00	.45
Region IV				
Alabama	0.00	.08	0.00	.08
Florida	0.00	.04	0.00	.04
Georgia	0.00	.03	0.00	.03
Kentucky	0.00	.07	0.00	.07
Mississippi	0.00	0.00	0.00	0.00
North Carolina	0.00	.11	0.00	.11
South Carolina	0.00	.01	0.00	.01
Tennessee	0.00	.14	0.00	.14
Region IV Total	0.00	.48	0.00	.48
Region V				
Illinois	0.00	.51	0.00	.51
Indiana	0.00	.18	0.00	.18
Michigan	0.00	1.43	0.00	1.43
Minnesota	0.00	.13	0.00	.13
Ohio	0.00	.65	0.00	.65
Wisconsin	0.00	.11	0.00	.11
Region V Total	0.00	3.01	0.00	3.01

Note: Total Industry Wastes = Potentially Hazardous Wastes.

TABLE E-48. (Continued)

EPA Region and State	Plant Size (Employees) 16	38	87	Total
Region VI				
Arkansas	0.00	.03	0.00	.03
Louisiana	0.00	.01	0.00	.01
New Mexico	0.00	.01	0.00	.01
Oklahoma	0.00	.01	0.00	.01
Texas	0.00	.20	0.00	.20
Region VI Total	0.00	.26	0.00	.26
Region VII				
Iowa	0.00	.04	0.00	.04
Kansas	0.00	0.00	0.00	0.00
Missouri	0.00	.08	0.00	.08
Nebraska	0.00	.03	0.00	.03
Region VII Total	0.00	.15	0.00	.15
Region VIII				
Colorado	0.00	.04	0.00	.04
Montana	0.00	0.00	0.00	0.00
North Dakota	0.00	0.00	0.00	0.00
South Dakota	0.00	0.00	0.00	0.00
Utah	0.00	.01	0.00	.01
Wyoming	0.00	0.00	0.00	0.00
Region VIII Total	0.00	.05	0.00	.05
Region IX				
Arizona	0.00	.06	0.00	.06
California	0.00	.48	0.00	.48
Hawaii	0.00	0.00	0.00	0.00
Nevada	0.00	0.00	0.00	0.00
Region IX Total	0.00	.54	0.00	.54
Region X				
Alaska	0.00	0.00	0.00	0.00
Idaho	0.00	0.00	0.00	0.00
Oregon	0.00	.01	0.00	.01
Washington	0.00	.06	0.00	.06
Region X Total	0.00	.07	0.00	.07
Total U. S.	0.00	7.76	0.00	7.76

APPENDIX F

DETAILED COST DATA ON SELECTED LEVEL II (SLUDGE DEWATERING) - LEVEL I (LANDFILL BURIAL) CASE STUDIES

APPENDIX F

DETAILED COST DATA ON SELECTED LEVEL II (SLUDGE DEWATERING) - LEVEL I (LANDFILL BURIAL) CASE STUDIES

Detailed capital and operating costs of nine selected Level II (with regard to sludge dewatering to about 20 percent solids) and Level I (with regard to landfill disposal) systems are presented in this Appendix. The detailed costs are based on information furnished by the electroplating plants. General descriptions of the plant circumstances are given in Table F-1. Detailed cost data for the nine case studies of Level II and I handlin and disposal systems are presented in Figures F-1 through F-9.

TABLE F-1. SUMMARY OF COST DATA FOR MINE SLUDGE DEWATERING (LEVEL II) AND DISPOSAL SYSTEMS (PROBABLY LEVEL I LANDFILL BURIAL)[(a)]

Case Study	System Characteristics	Volume of Sludge Handled liter/day	Volume of Sludge Handled gal/day	Capital Cost, (Dollars)	Unit Capital Cost $/liter/day	Unit Capital Cost $/gal/day	Operating Cost, $/Year	Unit Operating[(a)] Cost $/liter	Unit Operating[(a)] Cost $/gal
1. **California 333**	4-stage Clarifier, Contractor Hauling	23.8	63	6,475	271.54	1,027.79	2,068	0.40	1.51
2. **California 3199**	Vacuum Filter, and Contractor Hauling to Landfill	2,960	782	32,500	10.98	41.56	25,016	0.037	0.14
3. **Illinois 3022**	Filter, and Landfill Disposal	2,774	733	9,196	3.32	12.55	21,142	0.032	0.12
4. **Indiana D**	Filter Press, and Landfill Disposal	1,378	364	226,000	164.03	620.88	67,400	0.196	0.74
5. **Indiana E**	Clarifier, Centrifuge, Dewatering, Landfill Disposal	151	40	31,760	209.78	794.00	6,777	0.180	0.68
6. **Iowa M**	Vacuum Precoat Filter, Landfill Disposal	10,447	2,760	270,336	25.88	97.96	57,413	0.021	0.08
7. **Massachusetts**	Centrifuge, Landfill Disposal	80	21	14,700	184.94	699.99	5,970	0.301	1.14
8. **Michigan K**	Rotary Vacuum Filter, Contractor Hauling	174	46	30,102	174.75	661.43	13,225	0.293	1.11
9. **Minnesota N**	Dewater, Contractor Hauling	4,686	1,238	33,138	70.70	26.76	53,400	0.045	0.17

(a) Unit operating costs were based on a 250-day year, if the number of operating days per year was not provided.

(1) VOLUME OF WASTE HANDLED			
liters/day (gal/day)	23.8 (6.3)		
(2) CAPITAL COSTS	$	$ liter/day	$/gal/day
Design Cost	300	12.58	47.62
Land Cost	1,000	41.92	158.73
Site Preparation	175	7.32	27.73
Construction and Equipment Installation	3,500	146.78	555.56
Start-Up Costs	--	--	--
Downtime Losses	1,500	62.91	238.10
Other Costs	--	--	--
Total Capital Cost	6,475	271.54	1,027.79
(3) ANNUAL COSTS	$/year	$/liter	$/gal
Annual Capital Costs	864	0.161	0.61
Contractor Costs	360	0.069	0.26
Labor Cost	300	0.058	0.22
Materials Cost			
Chemical Cost	150	0.026	0.10
Testing and Analysis	300	0.058	0.22
Administrative Cost	112	0.026	0.10
Energy and Power Cost	--	--	--
Other Costs	--	--	--
Total Operating Cost	2,086	0.399	1.51
Revenues Received			
Net Operating Cost			

FIGURE F-1. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 1: CALIFORNIA 333

(1) VOLUME OF WASTE HANDLED			
liters/day (gal/day)	2,960 (782)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	2,000	0.68	2.56
Land Cost	1,000	0.34	1.28
Site Preparation	1,000	0.34	1.28
Construction and Equipment Installation	28,500	9.63	36.45
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	32,500	10.98	41.56
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	5,200	0.008	0.03
Contractor Costs	17,376	0.024	0.09
Labor Cost	1,500	0.003	0.01
Materials Cost	300	--	--
Chemical Cost	120	--	--
Testing and Analysis	200	--	--
Administrative Cost	220	--	--
Energy and Power Cost	100	--	--
Other Costs	--	--	--
Total Operating Cost	25,016	0.037	0.14
Revenues Received			
Net Operating Cost			

FIGURE F-2. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 2: CALIFORNIA 3199

(1) VOLUME OF WASTE HANDLED			
liters/day (gal/day)	2,774 (480)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	480	0.17	0.65
Land Cost	1,000	0.36	1.36
Site Preparation	36	0.01	0.05
Construction and Equipment Installation	7,680	2.77	10.48
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	9,196	3.31	12.54
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	1,342	0.003	0.01
Contractor Costs	6,000	0.008	0.03
Labor Cost	10,500	0.016	0.06
Materials Cost	--	--	--
Chemical Cost	200	--	--
Testing and Analysis	1,000	--	--
Administrative Cost	2,000	0.003	0.01
Energy and Power Cost	100	--	--
Other Costs	--	--	--
Total Operating Cost	21,142	0.032	0.12
Revenues Received			
Net Operating Cost			

FIGURE F-3. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 3: ILLINOIS 3022

(1) VOLUME OF WASTE HANDLED			
liters/day (gal/day)	1,378 (364)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	30,000	21.77	82.42
Land Cost	1,000	0.73	2.75
Site Preparation	25,000	18.15	68.68
Construction and Equipment Installation	170,000	123.39	467.03
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	226,000	164.04	620.88
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	37,000	0.108	0.41
Contractor Costs	1,200	0.003	0.01
Labor Cost	17,000	0.050	0.19
Materials Cost	500	--	--
Chemical Cost	--	--	--
Testing and Analysis	5,000	0.013	0.05
Administrative Cost	6,700	0.018	0.07
Energy and Power Cost	--	--	--
Other Costs	--	--	--
Total Operating Cost	67,400	0.196	0.74
Revenues Received			
Net Operating Cost			

FIGURE F-4. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 4: INDIANA D

(1) VOLUME OF WASTE HANDLED			
liters/day	151		
(gal/day)	(40)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	3,760	24.83	94.00
Land Cost	--	--	--
Site Preparation	--	--	--
Construction and Equipment Installation	28,000	184.94	700.00
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	31,760	209.77	794.00
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	5,200	0.137	0.52
Contractor Costs	--	--	--
Labor Cost	609	0.016	0.06
Materials Cost	38	--	--
Chemical Cost	--	--	--
Testing and Analysis	400	0.011	0.04
Administrative Cost	--	--	--
Energy and Power Cost	530	0.013	0.05
Other Costs	--	--	--
Total Operating Cost	6,777	0.180	0.68
Revenues Received			
Net Operating Cost			

FIGURE F-5. BREAKDOWN OF CAPITAL AND ANNUAL COSTS
FOR CASE STUDY 5: ILLINOIS E

(1) VOLUME OF WASTE HANDLED liters/day (gal/day)	10,447 (2,760)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	79,520	7.61	28.81
Land Cost	1,000	0.10	0.36
Site Preparation	9,040	0.87	3.28
Construction and Equipment Installation	180,806	17.31	65.51
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	270,366	25.88	97.96
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	42,500	0.016	0.06
Contractor Costs	--	--	--
Labor Cost	816	--	--
Materials Cost	156	--	--
Chemical Cost	6,360	0.003	0.01
Testing and Analysis	--	--	--
Administrative Cost	7,488	0.003	0.01
Energy and Power Cost	93	--	--
Other Costs	--	--	--
Total Operating Cost	57,413	0.021	0.08
Revenues Received			
Net Operating Cost			

FIGURE F-6. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 6: IOWA M

(1) VOLUME OF WASTE HANDLED			
liters/day (gal/day)	80 (21)		
(2) CAPITAL COSTS	$	$ liter/day	$/gal/day
Design Cost	1,300	16.35	61.90
Land Cost	1,000	12.58	47.62
Site Preparation	620	0.11	29.52
Construction and Equipment Installation	11,780	147.95	560.95
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	14,700	184.94	699.99
(3) ANNUAL COSTS	$/year	$/liter	$/gal
Annual Capital Costs	2,250	0.114	0.43
Contractor Costs	2,217	0.111	0.42
Labor Cost	400	0.021	0.08
Materials Cost	25	--	--
Chemical Cost	--	--	--
Testing and Analysis	200	0.010	0.04
Administrative Cost	778	0.042	0.16
Energy and Power Cost	100	0.005	0.02
Other Costs	--	--	--
Total Operating Cost	5,970	0.301	1.14
Revenues Received			
Net Operating Cost			

FIGURE F-7. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 7: MASSACHUSETTS F

(1) VOLUME OF WASTE HANDLED			
liters/day (gal/day)	174 (46)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	210	1.21	4.57
Land Cost	1,000	5.74	21.74
Site Preparation	1,434	8.24	31.17
Construction and Equipment Installation	27,298	156.78	593.43
Start-Up Costs	210	1.21	4.57
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	30,152	173.18	655.48
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	4,750	0.103	0.39
Contractor Costs	4,800	0.106	0.40
Labor Cost	1,200	0.029	0.11
Materials Cost	500	0.016	0.04
Chemical Cost	--	--	--
Testing and Analysis	--	--	--
Administrative Cost	1,725	0.040	0.15
Energy and Power Cost	250	0.005	0.02
Other Costs	--	--	--
Total Operating Cost	13,225	0.293	1.11
Revenues Received			
Net Operating Cost			

FIGURE F-8. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 8: MICHIGAN K

(1) VOLUME OF WASTE HANDLED liters/day (gal/day)	4,686 (1,238)		
	$	$ liter/day	$/gal/day
(2) CAPITAL COSTS			
Design Cost	3,101	0.66	2.50
Land Cost	1,000	0.21	0.81
Site Preparation	1,452	0.31	1.17
Construction and Equipment Installation	27,585	5.87	22.28
Start-Up Costs	--	--	--
Downtime Losses	--	--	--
Other Costs	--	--	--
Total Capital Cost	33,138	7.07	26.76
	$/year	$/liter	$/gal
(3) ANNUAL COSTS			
Annual Capital Costs	5,300	0.005	0.02
Contractor Costs	42,000	0.034	0.13
Labor Cost	5,160	0.005	0.02
Materials Cost	2,040	0.003	0.01
Chemical Cost	--	--	--
Testing and Analysis	1,800	0.003	0.01
Administrative Cost	3,870	0.003	0.01
Energy and Power Cost	--	--	--
Other Costs	4,200	0.003	0.01
Total Operating Cost	64,370	0.056	0.21
Revenues Received	13,320	0.011	0.04
Net Operating Cost	51,050	0.045	0.17

FIGURE F-9. BREAKDOWN OF CAPITAL AND ANNUAL COSTS FOR CASE STUDY 9: MINNESOTA N

APPENDIX G

TABULATION OF ORIGINAL DATA AND PLOTS OF PARAMETERS

APPENDIX G

TABULATION OF ORIGINAL DATA AND PLOTS OF PARAMETERS

The cost data and other parameters selected from the industry responses are tabulated in Table G-1. This tabulation shows the extent and nature of the data supplied by industry. The interpretation of these data in terms of nine selected case studies has been described in the section of the document entitled "Sludge Handling - Disposal Costs from Industry Responses."

As part of the approach to the cost analysis, the relationships between waste disposal costs and various plant operating parameters were examined. Some of the plots developed during such an examination are given in Figures G-1 through G-7. In the case of disposal contractor costs, some trends were thought to be visible. On the basis that contractor costs should be proportional to the quantity of waste disposed of, straight lines of positive slope were drawn through the data and upper and lower bounds were established parallel to the "best" line. It may be noted that, in general, the upper and lower bounds are approximately one magnitude away from the "best" line. For example, in Figure G-1, for a plating rate of 2,325 square meters per month (25,000 square feet per month), the range of contractor costs is from $10 to $1000 per month.

The data plotted in Figures G-5 through G-7 (operating costs) show no identifiable trends whatsoever.

TABLE G-1. TABULATION OF DATA FROM INDUSTRY RESPONSES[(a)]

	Size of Plant				Quantity of Sludge				Cost of Waste Handling, $/month	
			Number of Employees		Weight		Volume			
Plant Identification	Plating Rate, sq ft/month	Total Sales Volume, $/month	Total	Plating	kg/mo	lb/mo	liter/mo	gal/mo	Contractor Cost	Operating Cost
California #232	4,000		12	3			7,500	1,980		
California #269		90,000	80	4			3,000	792		100
California #333			35	30			7,500	1,980	30	750
California #339		250,000	90	50	1,361	3,000	1,190	314	50	
California #351A	15,000		150	50			23,725	6,268	250	NA
California #351B	50,000		65	25	476	1,050	395	105	90	
California #363	2,000	25,000	10	10					20	83
California #379		67,000	35	35			2,604	688	100	
California #509			422	22			78,840	20,830	750	2,500
California #519	7,000	100,000	37	34			1,980	523	75	
California #521		65,000	50	25			229	61	90	
California #705	1,000	4,000	1,300	15			562	148	100	
California #3199	100,000	1,250,000	700	700			88,300	23,330	1,448	2,420
Colorado M			4,500	30			6,855	1,810	434	13,042
Connecticut #3220	30,000	300,000	220	75			15,770	4,166	450	6,000
Florida #741A	10,000						3,312	875	2,000	1,558
Illinois #108		200,000	80	40	13,612	30,000	11,435	3,020	600	
Illinois #33	600,000	60,000	25	25			15,770	4,166	300	
Illinois	100,000		400	45			268,040	70,815	120	29
Illinois #3022		1,100,000	1,800	250	11,161	24,600	9,455	2,500	500	3,800
Indiana D	225,000		525	50	35,714	78,750	28,685	7,580	100	
Iowa M	911,120		2,000	30			217,590	57,490	0	4,160
Massachusetts F	8,385		750	8			1,270	335	246	725
Maine #947		20,000	250	190			11,830	3,125	1,200	
Michigan #420		210,000	80	60	1,512	3,333	1,270	335		
Michigan #389	240,000	100,000	75	60	227	500	167	44		
Michigan #1072			460	150	6,077	13,400	5,040	1,330	400	162
Michigan #3024	300,000	750,000	250	100			236,525	62,485	1,500	13,583

TABLE G-1. (Continued)

Plant Identification	Size of Plant				Amount Sludge				Cost of Waste Handling, $/month	
	Plating Rate, sq ft/month	Total Sales Volume, $/month	Number of Employees		Weight		Volume		Contractor Cost	Operating Cost
			Total	Plating	kg/mo	lb/mo	liter/mo	gal/mo		
Michigan W	410,800		260	20	454	1,000	395	105	122	921
Michigan KV					5,896	13,000	4,895	1,295		1,950
Minnesota #983	10,000	150,000	70	10			8,270	2,185	300	417
Missouri #738	267,000	1,900,000	650	50						100
New Jersey #3021	4,000	20,000	8	5	45	100	42	11	25	
Ohio #552			30	18	454	1,000	395	105	25	
Ohio M	17,000		550	27			4,415	1,165	25	
Ohio HA	1,260,000		475	30			108,000	28,535	600	
Pennsylvania #3001	900,000	1,250,000	450	100	34,030	75,000	28,370	7,495		4,583
Pennsylvania G	1,232,339	1,000,000	300	65	45,400	100,000	39,410	10,410	250	4,167
Utah #412B	18,000		3,000				229	61	4	
Virginia #404	15,000		4,000	20			1,585	418	300	270
Wisconsin #59	70,000	30,000	14	7					30	
Wisconsin #630	40,000	165,000	110	11	2,459	5,421	2,040	540		8
North Carolina #520	160,000		1,200	24	19,048	42,000	15,770	4,166	1,664	
Unknown #951	70,000		30,000	500	1,361	3,000	125,750	33,225	6,000	2,200

(a) It was assumed that approximately 1 gallon of sludge weighs about 10 pounds. The average concentration of sludge is 20 percent solids.

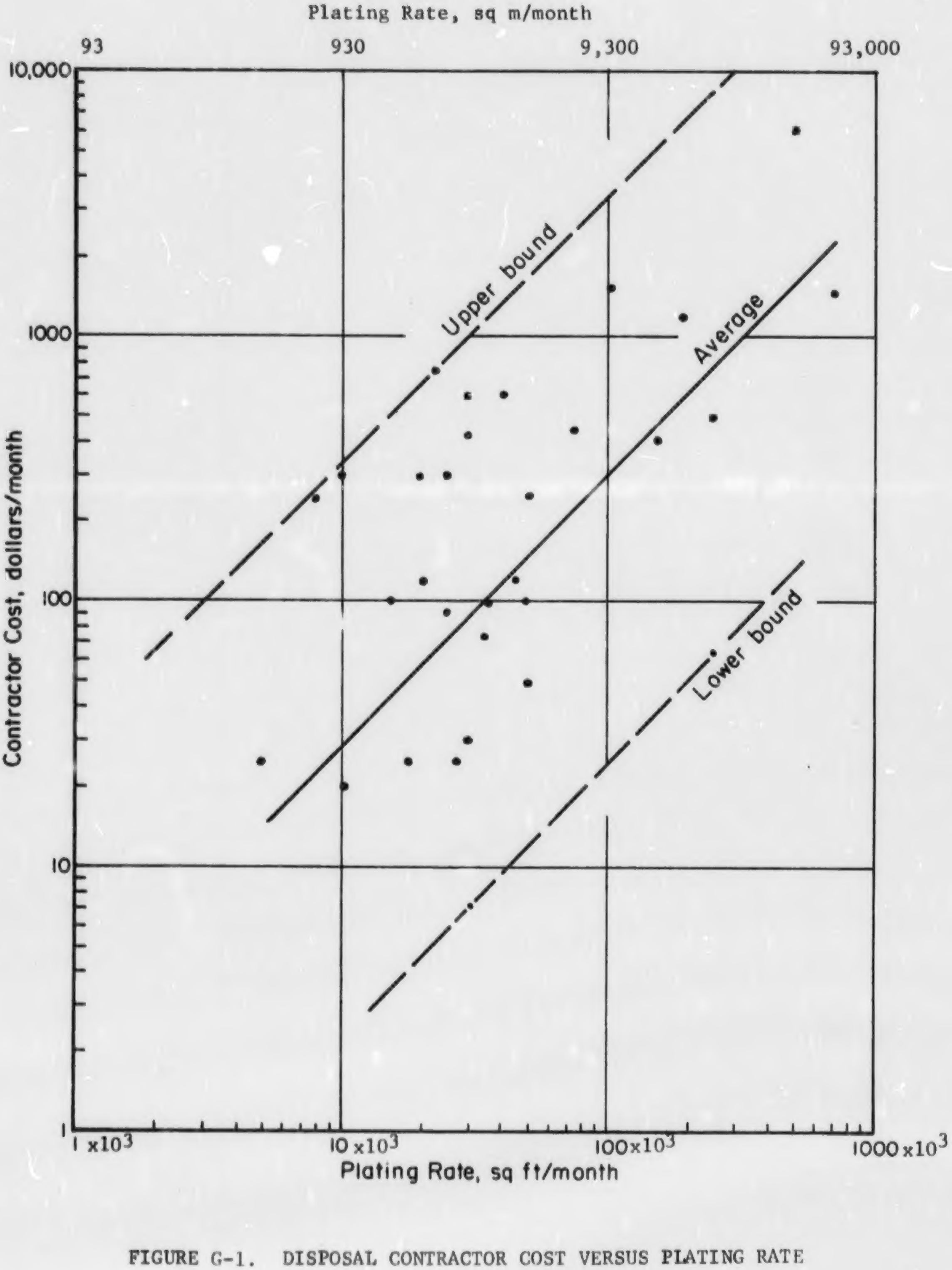

FIGURE G-1. DISPOSAL CONTRACTOR COST VERSUS PLATING RATE

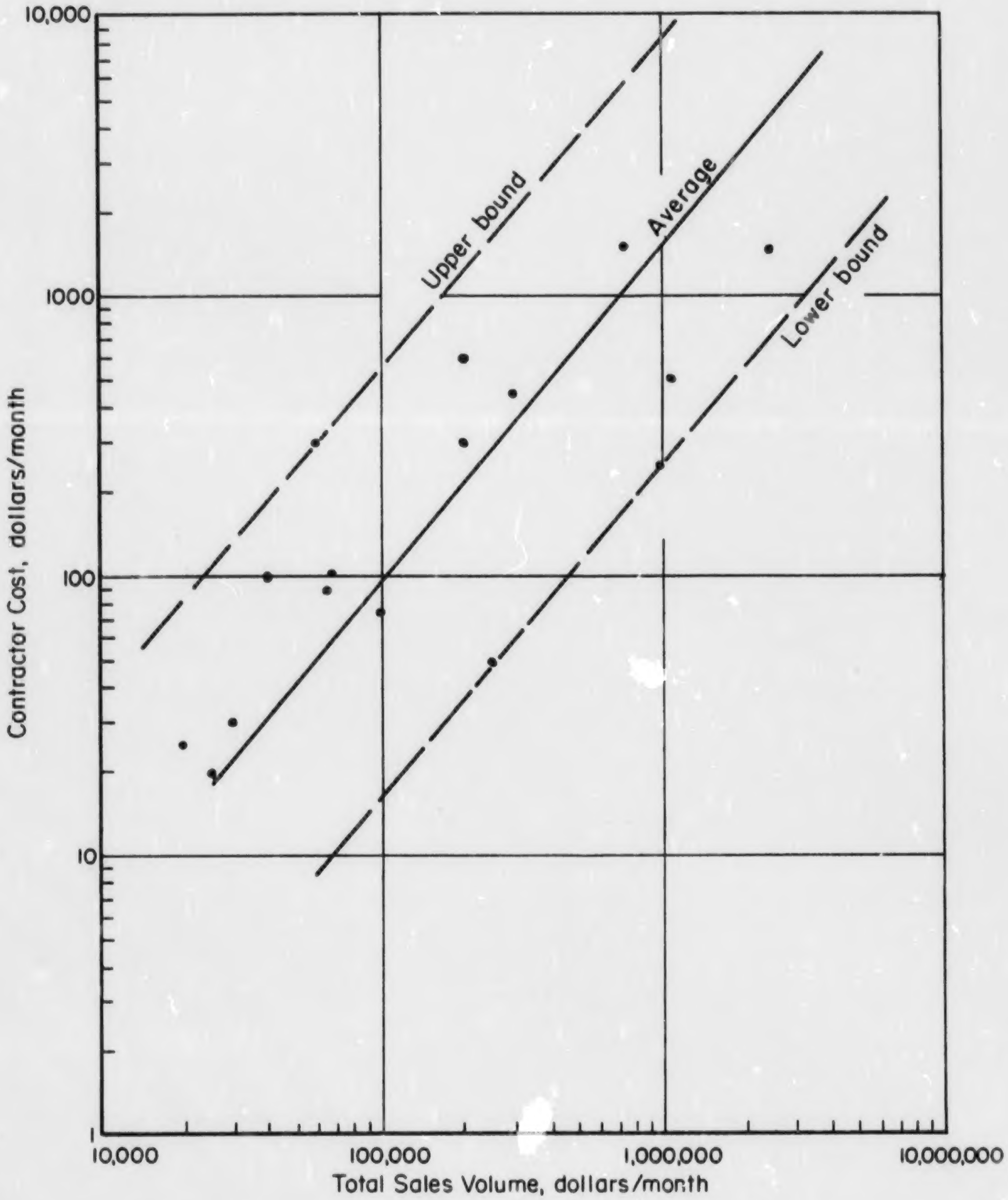

FIGURE G-2. DISPOSAL CONTRACTOR COSTS VERSUS TOTAL SALES VOLUME

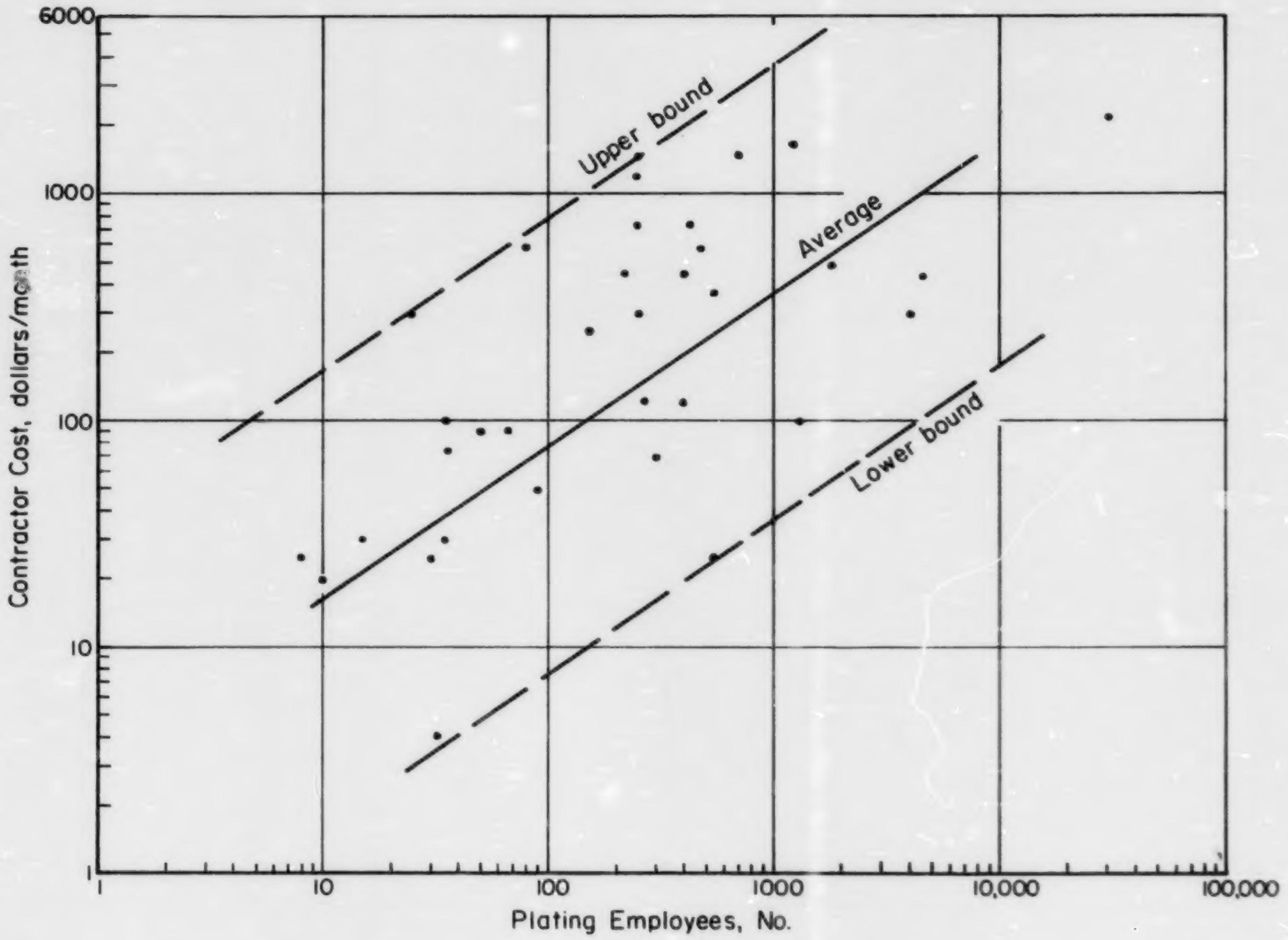

FIGURE G-3. DISPOSAL CONTRACTOR COST VERSUS PLATING EMPLOYEES

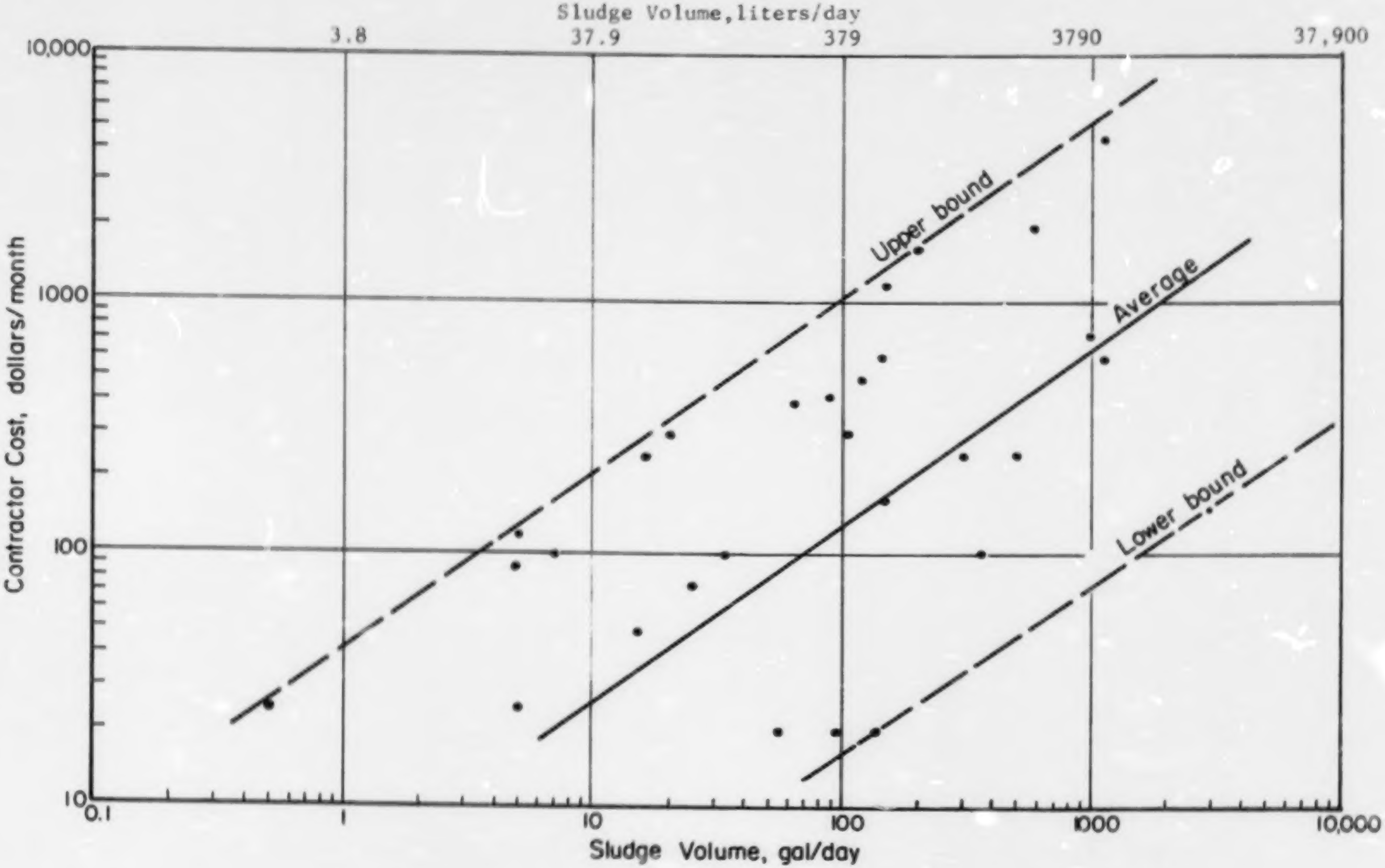

FIGURE G-4. DISPOSAL CONTRACTOR COST VERSUS SLUDGE VOLUME

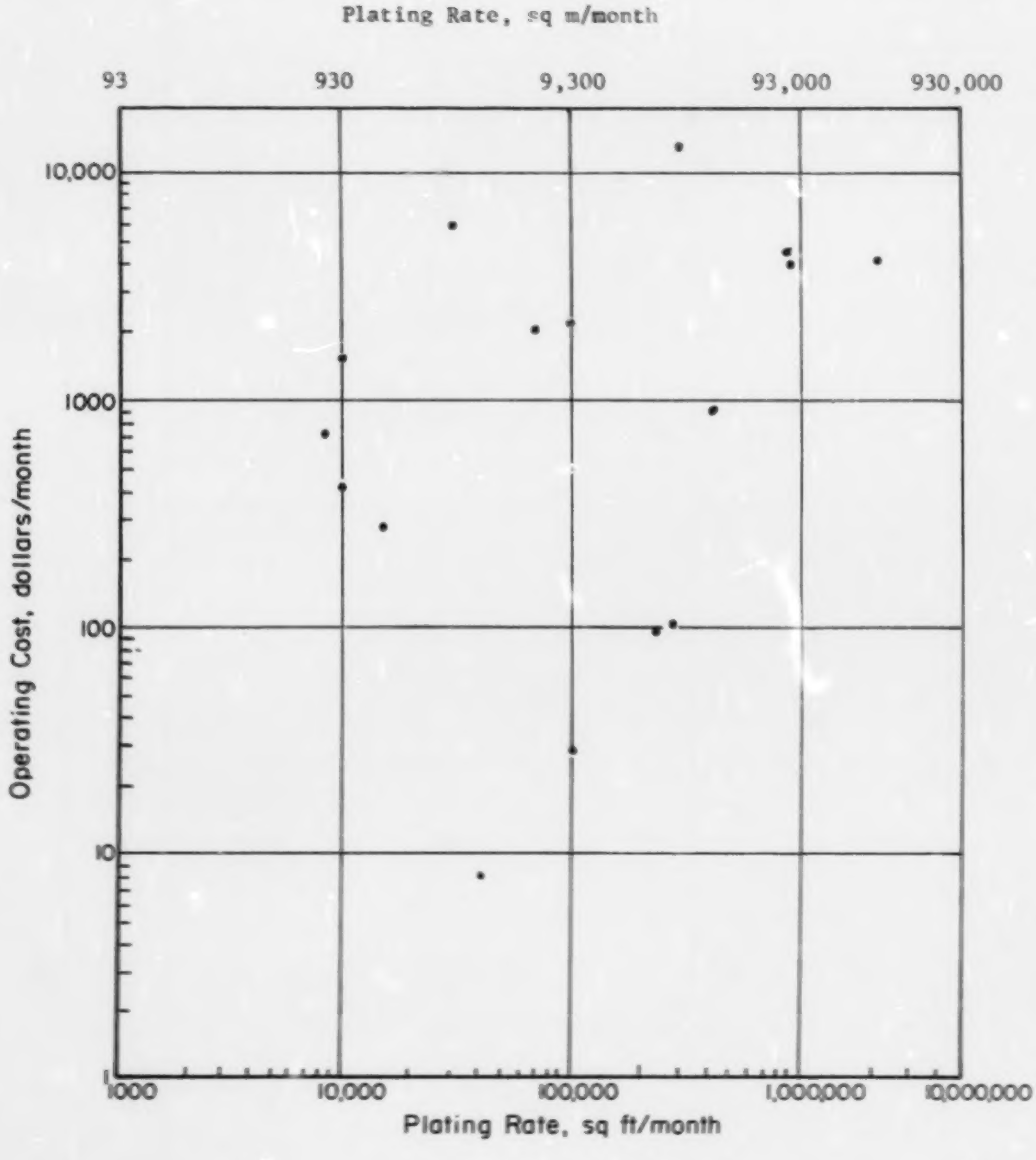

FIGURE G-5. DISPOSAL OPERATING COST VERSUS PLATING RATE

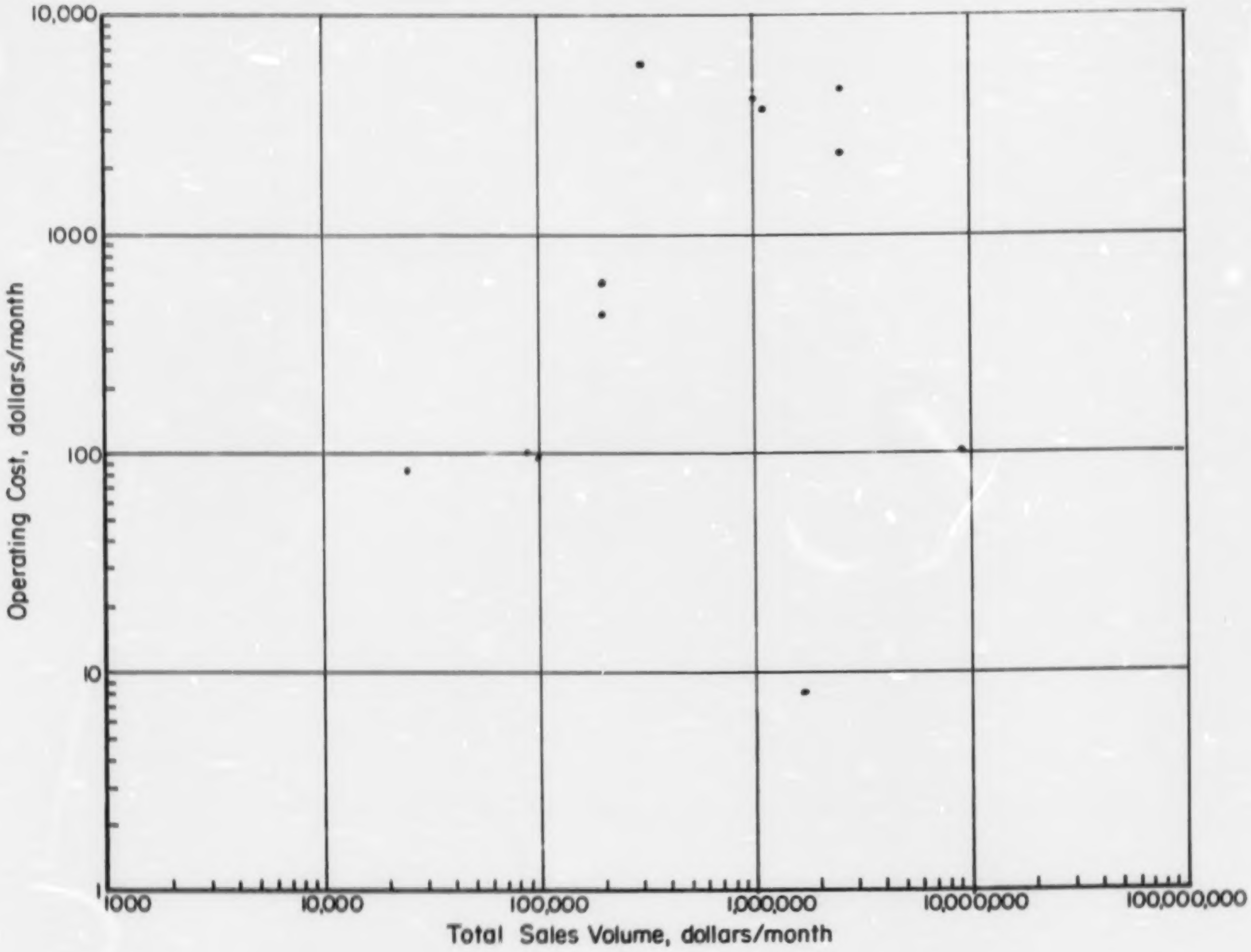

FIGURE G-6. DISPOSAL OPERATING COST VERSUS TOTAL SALES VOLUME

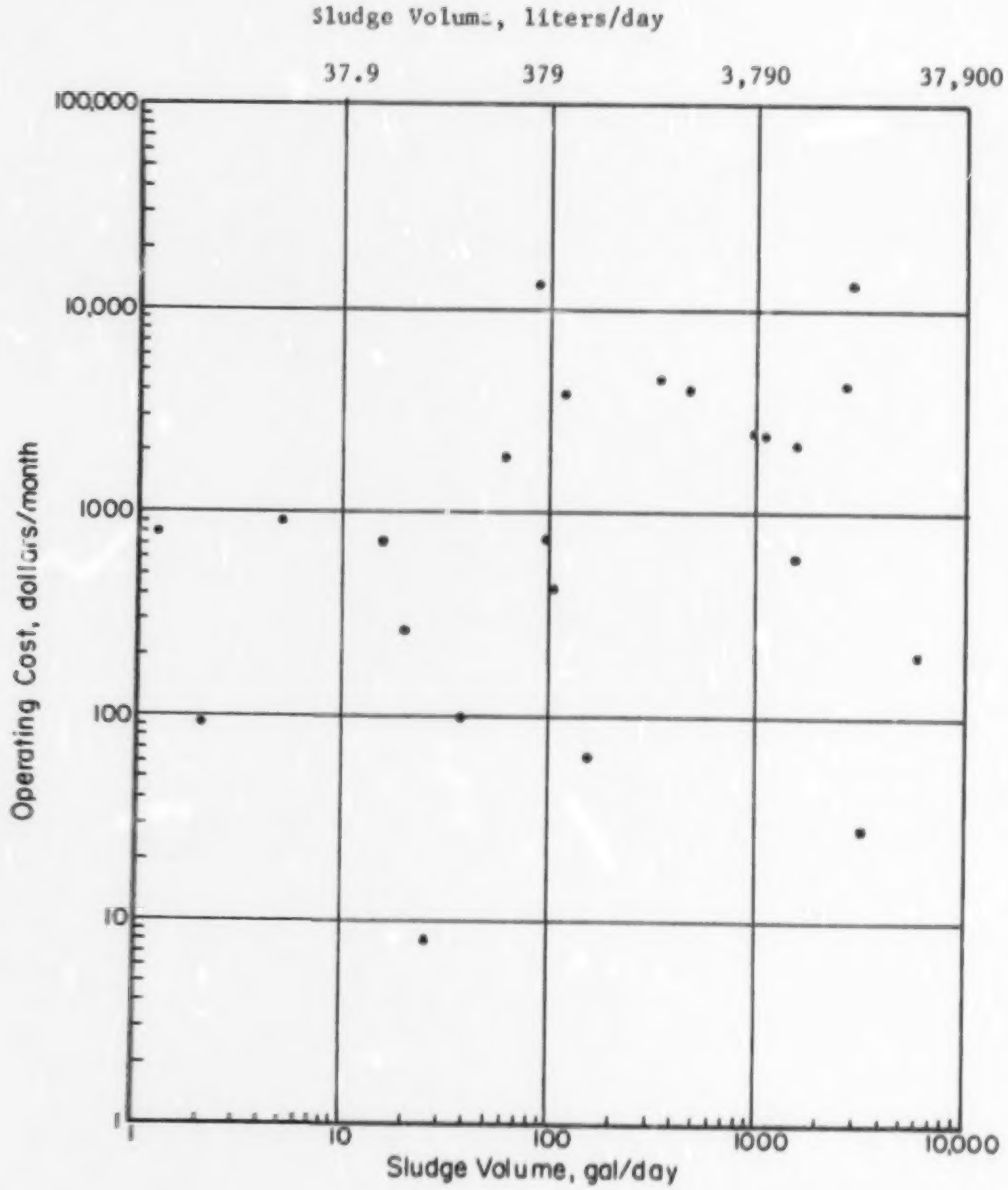

FIGURE G-7. DISPOSAL OPERATING COST VERSUS SLUDGE VOLUME

APPENDIX H

WASTE CHARACTERISTICS REPORTED BY ELECTROPLATING AND METAL FINISHING JOB SHOPS

TABLE H-1. WASTE CHARACTERISTIC REPORTED BY

Plant Code	Nature of Waste	Quantity[a] Lb/Year	Quantity[a] Gal/Year	Solids Content	Units	Asbestos	Arsenic	Beryllium	Cadmium	Chromium
500	Plating sludge			50%						
470	APC dust[2]	10,000								
470	WPC sludge[3]	5,000								
712	Plating sludge		5-6							
3011	WPC sludge		41,250		Ppm				NA[f]	463
33	WPC sludge		55,000	10%	Wt %	0	0	0	1	1
269	Stripping solution		9,000	1-33 Mg/l	Mg/l		0.01 to 0.07	0.0 to 3	4 to 13	1 to 3
526	WPC sludge		1,200							
526	Plating solutions		12,000							
526	Honing oils		2,400							
3024	WPC sludge		750,000	2-3%			0	0		M[e]
459	Polishing dust	2,400								
627	WPC sludge		13,750							
627	APC dust	13,750								
627	Plating solution		8,250							
389	WPC sludge		275,000	10%		A[h]	A	A	A	P
389	APC sludge	6,600								
390	Plating sludge	7,200		70%	Ppm				28	
521	Polishing dust	2,400								
521	Plating sludge	3,600		80%						
147	WPC sludge	1,300[i]		23%	Wt %[j]	NA	NA	NA	NA	1.3
552	Cleaner sludge	12,000								
339	Blasting grit	36,000								
3009	Cleaner sludge	110,000								
759	WPC sludge		1,375							
759	Plating solutions		1,925							
682	Plating sludge	360	68,750	Wt %	Wt %					
623	WPC sludge									P
623	Plating chemicals		275,000							P
393	Phosphate sludge	72,000								
393	Cleaner, grease	6,000								
363	Sump sludge			10%						
355		100								
163	APC dust	600								
138	Plating sludge		2,400	80%						
615	WPC sludge		2,200	20%					P	P
720	Dust		4,125							
720	Painting sludge		6,875							
479	Peening dust	1,200								
479	WPC sludge	Unknown								
479	Filter aid	2,400								
3030	Plating sludge	600								
3030	Bright dip sludge	240								
379	Strip solution		2,400							
379	Plating sludge		6,000	10%						
746	Plating sludge	300 to 360		30%						
13	WPC sludge		3,500							
272	Plating sludge		2,000	10-15%						
54	Plating sludge		11,000	20%						
[illegible]	Plating sludge	1,200								
565	APC dust									
565	Finishing abrasives									
565	Plating solutions									
519	Plating solutions		6,875		Mg/l					
108	WPC sludge	360,000		15%	%				2	0.1
110	Finishing sludge	18,000		50%						
110	Blasting dust	60,000								
IPC[11] 520	WPC sludge	500,000		90%	%					
IPC 509	WPC sludge		275,000	14%	Mg/l	A	A	A	A	800
IPC 601	Finishing Compounds	5,500								
IPC 603	Fabrication epoxy, glass	60,000								
IPC 602	Plating sludge	4,800		50%						
IPC 738	WPC sludge		550,000	2%	Ppm				50	50
IPC 909	Finishing Chemicals		312,000	10	Mg/l	A	A	A	A	A
IPC 3220	WPC sludge		55,000	%						
IPC 3199	WPC sludge		84,000	20	wt %	P	A	A	A	0.3
IPC 3199	Plating chemicals		198,000	15%	Mg/l	A	A	A	A	2
IPC 3199	APC sludge	36,000		90	Wt %	A	A	A	A	A
IPC 3204	WPC sludge		2,040		Wt %					
IPC 351	Plating solutions		72,000							
IPC 351	Finishing dust		4,125							
IPC 951	Cleaning sludge	36,000		95%	Wt %					

ELECTROPLATING AND METAL FINISHING JOB SHOPS

Copper	Cyanide	Iron	Lead	Magnesium	Mercury	Nickel	Selenium	Zinc	Phosphates	Sulfates	Oil and Grease	Other	Gold	Silver	Palladium	Tin
3710		1500				6600		970								
1	1	5	1.2		0	1	0	35								
1 to 3	5 to 8					15 to 50		2 to 30			2 to 3					
M	T(f)	T	T		0	M	T	P(g)					T	T	T	
A	T	P	A	P	A	P	A	T								
	20							85								
0.4	NA	0.5	NA	NA	NA	1.1	NA	0.2	NA	NA	NA					0.2
2		5				3										
P	P															
P	P							P								
P		P														
		P														
						3000										
		4						14								
0.9			0.3						0.1	0.1						
50	NA	NA	7	NA	A	NA	A	NA	P							100
250			50			20		20								
3000	A	P	P	A	A	A	A	A	P	P	A					P
40			5			10				15						10
0.1	A	0.01	0.005	0.01	T	0.1	A	T	0.1	1.5	0.05					
8000	A	P	NA	NA	T	20	A	T	50	150	3					
0.2	A	P	A	P	A	T	-	T	A	A	2					
45			18			15										
50																

TABLE H-1

Plant Code	Nature of Waste	Quantity[a] Lb/Year	Quantity[a] Gal/Year	Solids Content	Units	Asbestos	Arsenic	Beryllium	Cadmium	Chromium
IPC 951	Plating solution		360,000		Oz/gal					6
IPC 953	Cleaning solvents		42,000							
IPC 947	WPC sludge		41,250	10%						
	WPC sludge	30-40[i]								
	APC dust	9600-14,400								
	Solvent sludge									
	WPC sludge		82,500	5%						
	WPC sludge		825,000	15-20%						
	WPC sludge	1,320,000		15%	Ppm					510
	Finishing acids		376,750							
	Drawing sludge		120,000		Mg/l				0.15	2
	APC sand	500								
	Tumbling sludge	1,000		80%						
	Filter sludge	200								
	Grinding sludge	500		90%						

(a) The reported amounts were equilibrated to lb/year and gal/year. The factors used were 5 1/2 days per week and 50 weeks or 12 months per year.
(b) APC = air pollution control
(c) WPC = water pollution control
(d) NA = not analyzed
(e) M = major constituent
(f) T = trace constituent
(g) P = present
(h) A = absent
(i) Cubic yard per year.
(j) Wet basis
(k) IPC = Institute of Printed Circuits

(continued)

Copper	Cyanide	Iron	Lead	Magnesium	Mercury	Nickel	Selenium	Zinc	Phosphates	Sulfates	Oil and Grease	Other	Gold	Silver	Palladium	Tin
7																
765			276	18 000			805									
100					T	75										

APPENDIX I

GLOSSARY

Acid Dip

An acidic solution used to eliminate a passive condition on a surface prior to electroplating (especially after the workpiece has been processed in an alkaline solution).

Alkaline Cleaning

Removal of grease or other foreign material from a surface by means of alkaline solutions.

Anode

The positive electrode in a plating bath; it may be soluble or insoluble relative to the surrounding solution.

Anode Bag

Woven textile materials fitting over soluble anodes to collect the insoluble particles which fall as the anode is consumed.

Anodizing

The production of a protective oxide film on aluminum or other light metals by passing a high voltage of electric current through the bath in which the metal is suspended. The metal serves as the anode. The bath usually contains sulfuric, chromic, or oxalic acid.

Automatic Plating

(1) Full - plating in which the cathodes are automatically conveyed through successive cleaning and plating tanks.

(2) Semi - plating in which the cathodes are conveyed automatically through only one plating tank.

Barrel Plating

The electroplating of bulk materials (usually small) in rotating containers which are normally perforated to allow access and change of plating solutions during processing.

Basis Metal or Material

That substance of which the workpieces are made and that receives the electroplate and the treatments in preparation for plating.

Batch Treatment

Treatment of the electroplating rinse water which is collected in holding tanks. Water is not allowed to leave the tank until treatment is completed.

Bright Dip

A solution used to produce a bright surface on a metal.

Buffing

An operation for producing smoothness, satin, brushed, or lustrous finishes on metal products.

Captive Operation

Electroplating facility owned and operated by the same organization that manufactures the workpieces.

Carbon Adsorption

The use of activated carbon for the removal of metal ions from wastewaters by adsorption.

Cathode

The electrode in an electrolyte solution, on which the reducing reactions occur, i.e., discharge of positive ions or formation of negative ions. In electroplating the cathode recovers the deposit.

Centrifuge

Equipment used for partial dewatering of sludge up to 20 percent solids content.

Chelating Agent

A compound used as a bath additive, capable of complexing metal ions by forming stable, nonionic molecules.

Chemical Brightening

A process in which a material is added that induces the formation of a bright plate or improves the brightness of the deposit.

Chemical Etching

The dissolution of a metal coating in part or in total from its base.

Chemical Metal Coloring

The production of desired colors on metal surfaces by appropriate chemical or electrochemical action.

Chemical Polishing

The smoothing of a metal surface by immersion in a chemical solution to remove surface irregularities.

Chromating

A chromate coating, normally produced on zinc, cadmium, aluminum, magnesium, and copper alloys in solutions to provide corrosion protection or paint adhesion.

Chrome-Pickle Process

Forming a corrosion-resistant oxide film on the surface of magnesium-base alloys by immersion in a bath of an alkali dichromate solution.

Clarifier

A baffled tank used to accomplish liquid-solids separation in a waste treatment process.

Clarifier Under-flow

A sludge containing 1 to 2 percent solids after liquid-solid separation.

Closed-Loop Evaporation System

A system used for the recovery of chemicals and water from a plating line. An evaporator concentrates flow from the rinse water holding tank. The concentrated portion of the solution is returned to the plating bath, and the distilled water is returned to the final rinse tank. The system is designed for recovering 100 percent of the chemicals, normally lost in the dragout, for reuse in the plating process.

Continuous Treatment

A chemical waste treatment operation which operates uninterruptedly as opposed to batch treatment; sometimes referred to as flow-through treatment.

Conversion Coating

A coating produced by chemical or electrochemical treatment of the metallic surface that gives a superficial layer containing a compound of metal to protect against oxidation or to provide a surface for paint bonding.

Current Efficiency

The percentage of the applied direct current in an electrolytic process used to produce the coating or prepare the surface.

Deburring

A finishing operation to remove burrs and break edges by filing, polishing, tumbling, or electropolishing.

Deoxidizing

The removal of an oxide film from an alloy such as aluminum oxide.

Descaling

The process of removing scale or metallic oxide from metallic surfaces.

Desmutting

The removal of smut, generally by chemical action.

Dragin

The water or solution that adheres to the workpieces removed from the bath, and is thus carried to a subsequent bath.

Dragout

The solution that adheres to the workpieces removed from the bath, more precisely defined as that solution which is carried past the edge of the tank.

Dying

The impregnation of the workpiece surface with organic dyes to produce color on metals. The process is not often applied to anodized aluminum.

EDTA

Abbreviation for ethylenediamine-tetraacetic acid.

Electrobrightening

Electrolytic brightening (electropolishing) produces smooth and bright surfaces by electrochemical action similar to those that result from chemical brightening.

Electrochemical Machining (ECM)

An anodic process for removing metal at a high rate (0.025 to

0.13 cm/min [0.02 to 0.05 inch per minute]), and to form a predetermined shape, contour, slot or hole. The workpiece (anode) is held in a fixture which confines the electrolyte flowing at fast speeds.

Electrodialysis

The separation of ions in solution through an ion-specific membrane with the application of an electrical potential.

Electroless Plating

Deposition of a metallic coating by a controlled chemical reduction that is catalyzed by the metal or alloy being deposited.

Electropainting

The anodic or cathodic deposition of paints on the workpiece from emulsions used generally as a prime coat for future finishing.

Electroplating

The electrodeposition of an adherent metallic coating upon the basis metal or material for the purpose of securing a surface with properties or dimensions different from those of the basis metal or material.

Electroplating Process

An electroplating process includes a succession of operations starting with cleaning in alkaline solutions, acid dipping to neutralize or acidify the wet surface of the parts, followed by electroplating, rinsing to remove the processing solution from the workpiece, and drying.

Electropolishing

An electrolytic corrosion process which increases the percentage of specular reflectance from a metallic surface.

Electrostatic Precipitation

The use of an electrostatic field for precipitating or rapidly removing solid or liquid particles from a gas in which the particles are carried in suspension.

Filters

(1) Equipment used to remove suspended solids from plating solutions.

(2) Rotary vacuum and pressure filters for partial dewatering of sludge up to 45 percent solids content.

Grit

The size of abrasive particles used in metal surface preparation; grit size is expressed in various terms including standard sieve mesh sizes, or various industrial letter or number designations.

Grinding

The removal of metal or metal coatings from the workpiece by mechanical abrasion to shape and size.

Heavy Metals

All metals in the periodic table with the exception of alkali, alkaline earth, the lanthanide and actinide series. In waste treatment technology the term refers to metals which can be separated by precipitation.

Hot Dipping

A method of coating one metal on another to provide a protective film.

Hydrogen Embrittlement

The embrittlement of a metal or alloy caused by the absorption of hydrogen during the pickling, cleaning, or plating process.

Immersion Plate

A metallic deposit produced by a displacement reaction in which one metal displaces another from solution, for example:

$$Fe + Cu^{++} \longrightarrow Cu + Fe^{++}.$$

Independent Operation

Job shop or contract shop in which electroplating is done on workpieces owned by the customer.

Integrated Chemical Treatment

A waste treatment method in which the chemical rinse tank is inserted in the plating line between the process tank and the water rinse tank. The chemical rinse solution is continuously circulated through the tank and removes the dragout while reacting chemicals with it.

Ion-Flotation Technique

Treatment for electrolyzing the rinse waters (containing chromium and cyanide) in which ions are separated from solution by flotation.

Job Shop

A contract shop in which electroplating is done on workpieces owned by the customer.

Passivating

Providing a workpiece with a coating or surface condition which is resistant to oxidation and tarnish.

Phosphating

The process of forming a rust-resistant coating on iron or steel by immersing in a hot solution of acid manganese, iron, or zinc phosphate.

Pickle

An acid solution used to remove oxides or other compounds related to the basis metal from the surface of the metal by chemical or electrochemical action.

Pickling

The removal of oxides or other compounds related to the basis metal from its surface by immersion in a pickle.

Polishing

The smoothing of a surface by abrasive particles which are attached to a belt or wheel with adhesives.

Precious Metal

Gold, silver, platinum, etc.

Rack Plating

Electroplating of the workpieces mounted on racks designed for the plating operation.

Reverse Osmosis

A recovery process in which the more concentrated solution is put under a pressure greater than the osmotic pressure to drive water across the membrane to the dilute stream while leaving behind the dissolved salts.

Rochelle Salt

Sodium potassium tartrate: $KNaC_4H_4P_6 \cdot 4H_2O$.

Shot Blasting

The dry abrasive cleaning of metal surfaces by impacting the surfaces with high velocity abrasive particles.

Sludge

The residue in the clarifier of a chemical waste treatment process, or any accumulation of semisolids at the bottom of a tank or vessel.

Soil

A generic term applied to metal surfaces contaminated by mineral, animal, vegetable and compounded oils, buffing compound residues, smuts, minute particles, cleaning and pickling residues and shop dirt.

Waste

All wastes generated in metal finishing processes and which are destined for land disposal. These wastes consist of metal-hydroxide sludges, solvents, metal scraps, dusts, chemicals, and polishing and buffing compounds and materials.

Spent Bath Solution

Solutions which have become inoperative because of the consumption of active constituents, decomposition, depletion of active ions, dilution, and/or an increase in the contaminant concentrations.

Stop-Off

Organic coatings resistant to solution attack, applied to portions of a workpiece which is not to be processed in an electroplating and metal finishing operation; i.e., a "mask".

Strike

(1) Noun - a thin coating of metal (usually less than 0.0001 inch in thickness) to be followed by other coatings.

(2) Noun - a solution used to deposit a strike.

(3) Verb - to plate for a short time, usually at a high initial current density.

Stripping

Removal of an electrodeposit or other coating by a chemical agent or reversed electrodeposition.

Water Treatment Sludge

The residue in the clarifier of a chemical waste treatment process for rinse waters, solution dumps and spills from metal finishing processes.

Workpiece

The item to be electrocoated, treated, or finished.

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